Ten Years of Reform of Chinese Science and Technology: An International Review of Experiences

A report commissioned by the State Science and Technology Commission of China and the International Development Research Centre, Canada

December 1995

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International Development Research Centre
Centre de recherches pour le développement international

21 December 1995

Ms. Zhu Lilan,
Vice Chairperson,
SSTC

Dear Zhu Li-Lan,

I have much pleasure in enclosing our Mission Report on "Ten Years of Reform of China's Science & Technology". Our observations and impressions are based on the written material translated into English by SSTC staff, and mostly derived from the 1995 White Paper on Science & Technology Policy, together with the three week visit we made in November 1995. During that visit we met with a wide range of science and technology policy makers, those concerned with policy implementation, and those effected by the science and technology reform, in the Provinces of Shaanxi, Liaoning, and Guangdong, and in the cities of Beijing and Shanghai. These personal observations and impressions have been supplemented by some additional impressions gained by reading recent secondary reviews.

In reaching our conclusions we followed the process adopted by many similar reviews which have been carried out in the OECD countries. We have relied almost exclusively on what has been written by Chinese authors and what we were told by Chinese individuals. We have not made our own detailed evaluations of institutions or programs. Out report is a mirror reflecting back what we read or were told. The filters through which information passed on its way to the mirror however were our own experiences and knowledge of our own societies. This influenced the questions we asked and our interpretation of the replies. We hope that our mirror is slightly concave so that our views are focussed!

We have included a brief description of the Chinese science and technology institutions and also of the history of the reforms. We felt it was important that we state what our understanding is on these issues. If we are wrong in that understanding then our impressions may be distorted. We have also focussed our report on the impact of the reforms on the five themes of basic research, high technology, traditional State enterprises, agriculture research and rural development, and environment and social development. These were the issues to which you had asked us to pay particular attention.

We look forward to our return to China for more detailed discussions on our report and its conclusions. As you know it was never the intention of the Review to make recommendations to the SSTC. Our task was to raise issues and ask questions. We hope our report makes a modest contribution to the way in which you and your colleagues consider the evolution of the science and technology policy reforms.

Finally, I would like to express our sincere gratitude to the many people throughout China who gave their time so generously to answer our many questions.

Yours Sincerely,

Geoffrey Oldham

Geoffrey Oldham
Head,
IDRC/SSTC S&T Review Mission to China

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Chapter 1: Introduction

The origins of this particular review of China's experience in the reform of its science and Technology system go back to a conversation between the Chairman of the State Science and Technology Commission of China, (SSTC) Dr Song Jian, and the President of the International Development Research Centre of Canada, (IDRC) Dr Keith Bezanson, held in Beijing in 1994. They noted that 1995 would be both the Tenth Anniversary of some of the major S&T reforms in China and the Fifteenth Anniversary of cooperation between SSTC and IDRC in the financing and management of a program of R&D in support of China's development. To mark the dual anniversary, they decided to jointly commission a Review of the Chinese experience of S&T Reform, particularly in the last decade, and agreed that the methodology which would suit the task would be that which had been developed by the Organization for Economic Cooperation and Development (OECD) in Paris for the purpose of reviewing the S&T Policies of the industrialised countries.

As a result of a detailed agreement between SSTC and IDRC, the following terms-of-reference were set for the Review:

Terms of Reference

Components and Objectives of Evaluation

The overall objective of this review is to assist Chinese policy makers as they assess the impact of their reform policies and decide on whether modifications to these policies should be made. The review will focus primarily on the science and technology policy reforms initially introduced by the SSTC in 1985.

The review will consist of three phases:

a) the gathering of background information for the project as discussed with Mr. James Mullin, a consultant engaged for this purpose, in early July 1995. The project will be guided by the standard OECD country review formula;

b) the review visit of the international team towards the end of 1995; and

c) the final meeting.

Following on establishing these terms, the two sides agreed on five substantive areas of concentration for the Review and on the composition of a ~~six~~ person, international team of experts to carry out the review. X

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The Specific Areas for priority attention were

Basic Research
High Technology Industries
State-owned Enterprises
Agriculture and Rural Development
Environment and Social Development

Membership of the team is listed in Appendix 1.

Method of Work

The review was carried out in three steps.

First, a preliminary visit to Beijing was made by one of the Team, in July 1995, to reach agreement on the background documentation to be provided by SSTC to the international Mission. It was agreed that SSTC would provide English-language documentation, including translations of key chapters of the recent White Paper on S&T Policy, together with translations of a series of policy studies from the National Research Centre for S&T for Development (NRCSTD) and the Institute of Science Policy and Management of the Chinese Academy of Sciences. In addition, copies of the English-language Edition of NRCSTD's Journal 'Forum on Science and Technology in China" were also made available.

Second, the Mission visited China during the period November 9 to December 1, 1995 for an extensive series of meetings with scientists, engineers, managers and officials. The itinerary followed by the Mission is set out in Appendix 2. These in-depth interviews formed the basis of this present report which was drafted by the Mission at the completion of its stay in China. It was the intention of the review to look at the S&T reforms in China in the light of our understanding of how patterns of research and innovation are evolving in the industrialised countries. It was not a task of the Mission to recommend particular policy options for China - that is a task which is appropriately the responsibility of the Government of China and of the Chinese institutions which are engaged in S&T.

Third, a final meeting will be held in Beijing to permit SSTC officials to discuss with the Mission their findings and impressions. This meeting will take place in March 1995 and a set of notes on the meeting will be appended to the final published version of this report.

Some Caveats

Readers of this Report should bear in mind the highly selective nature of the evidence gathered during the work of the Mission.

Given the brevity of its visits, there were many important areas of Chinese S&T activity entirely untouched by the Mission. For example, we were unable to touch areas of science like medicine or forestry, we visited no 'Big Science" facilities and discussed, without visiting, a number of key new institutional forms such as the key national laboratories and the engineering research centres of SSTC, the State Education Commission and the World Bank.

We have also encountered the problem of interpreting Chinese statistics, some of which (eg on S&T 'achievements') are based on definitions with which we are unfamiliar.

However, despite these caveats, we happily acknowledge the great openness of our Chinese hosts who often went to great lengths to answer our many questions.

The Structure of the Report.

The report is divided into three principal parts:

Part 1 - the Main Report of the Mission - represents our attempt to summarize the principal impressions we gained concerning S&T reform in China. We begin with a short series of general impressions which provided the backdrop to our understanding of what has transpired in Chinese S&T over the last decade. We then attempt to summarize the principal debates on Chinese S&T Policy which we encountered during our Mission, adding, where possible, some remarks on relevant international experience or practice which we believe could be useful in the present context in China. Thirdly, we raise a set of issues which we believe are not receiving the attention, in China, which we would argue they merit. Finally, we add a few brief observations on current S&T policy in China as articulated in the May 1995 Decision on Accelerating S&T Progress of the State Council.

Part 2 - The Detailed Observations of the Mission - begins with a lengthier discussion of our understanding of the S&T reform process in China and then introduces what we consider to be an important concept - the concept of a national system of innovation - which is helpful in conceptualizing the range of functions which need to be fulfilled if the goals of China's S&T Reforms are to be fully attained. We then provide commentary on the five specific areas designated in our terms of reference (Basic Research, High Technology, State-owned enterprises, Agricultural R&D and Environment and Social Development.)

Part 3 - An Account of Final Discussions - will be drafted in March, following upon the scheduled meetings in Beijing.

Explanation of OECD approach - what to expect & not expect.

Part 1: The Main Report of the Mission

GENERAL FINDINGS

Intro. P - (Communist Party of China)

S&T Reforms

Since at least 1978, China has encouraged experimentation in its S&T system as a means of arriving at reforms, and has periodically summarised the main directions of reform in authoritative "Decisions" of either the State Council or of the Central Committee of the CPC. (Particularly the March 1985 *Decision on the Reform of the Science and Technology Management System* and the May 1995 *Decision on Accelerating Scientific Progress)* This has been a creative method of approaching a complex set of issues and the main decisions have established a sensible over-all framework for a science and technology policy for a modernizing economy. In some cases, such as in environmental policy, the decisions already taken in China are ahead of most other countries in the world.

The 1993 "Decision on some issues for the establishment of a Socialist Market Economy" appears to have injected added impetus to S&T reforms in some parts of China and has given rise to anothe round of creative experimentation.

We have taken the March 1985 Decision as our main point of departure, and have also considered the effects of other reform initiatives indicated in the 'timeline' which follows.

The March 1985 Decision on
The Reform of the Science and Technology Management System

I Modern science and technology constitute the most dynamic and decisive factors in the new productive forces......We should reform China's science and technology management system resolutely and step by step in accordance with the strategic principle that our economic construction rely on science and technology and that our scientific and technological work must be oriented to economic construction......Regarding the operating mechanism, it entails reforming the funding system, exploiting the technology market and overcoming the defects of relying on purely administrative means in science and technology management, with the state undertaking too much and exercising too rigid a control.

II Funding for research institutes should be reformed so as to practise classified management over the operating expenses which is suited to different types of scientific and technological activities [This led to different state-funding responsibilities for different kinds of S&T activities and institutions...Ed]

III We should promote the commercialization of technological achievements and exploit the technology market so as to suit the needs of the socialist commodity economy.

IV In restructuring the science and technology system, emphasis should be placed on encouraging partnership between research, educational and designing institutions on the one hand and production units on the other and on strengthening the enterprises' capability for technology absorption and development.

V The management system in agricultural science and technology should be reformed so as to serve the restructuring the rural economy and facilitate its conversion to specialization, commercialization and modernization.

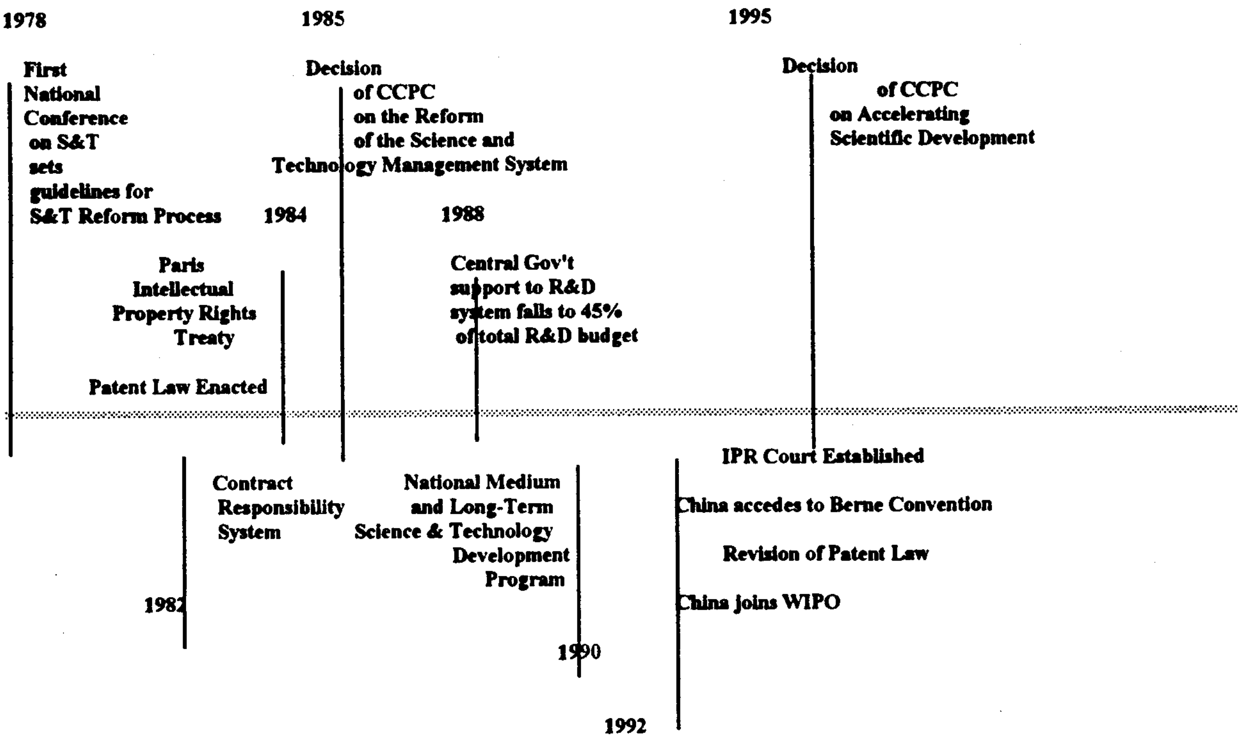
VI To ensure sustained progress in economic and scientific and technological development, it is necessary to deploy our scientific research forces rationally and in depth.

VII More decision-making power should be granted to research institutes, and macromanagement of scientific and technological work by government organs should be improved.

VIII Opening to the outside world and establishing contact with other countries is a basic and long-term policy in China's scientific and technological development.

IX Management of scientific and technological personnel should be reformed to create a situation favourable to the emergence of large numbers of talented people who can put their specialized knowledge to best use.

Ref. ?



A Timeline of Significant Policy Events in the Reform of China's S&T System

The Problems of Implementation

While the Mission believes that the broad directions of reform set out in the State Council's decisions are appropriate to China's overall development, we have observed that there have been great variations in the level of implementation of reforms in different parts of the country and in different institutions. Not surprisingly, in the eyes of the Mission, there is a strong correlation between successful and innovative attempts at reform and the presence of strong, entrepreneurial management. Equally, where management retains the mind-set of the command economy, reform has been slow.

The Overall Process of Reform in China

Reform of China's S&T System is only one element of an on-going and long-term process of reform of its national economy and social welfare system. China is emerging from a 'command economy' which has produced, contrary to its intentions, a huge and, to the outsider, confusing array of institutions in all sectors which are almost invariably over-staffed and which often duplicate the work done by others. There is a need to continue the process of rationalization which has been begun by the reduction of government support to many of these institutions. However, this process is substantially impeded by the difficulties faced by institutions in coping with the significant overhead costs which they have to bear in the provision of housing, health care, education and other services to their employees, both present and retired, and to their families. . A key to tackling some of these important barriers to institutional reform will be the as-yet incomplete process of reform of the social welfare system. Until a new system, geared to the demands of the emerging 'socialist market economy', is in place, many necessary structural changes, including changes in the S&T System, will not be possible.

International factors impinging on China's Reform Process

When China decided to develop its "open door policy" in the late 1970's, one of the main reasons was to acquire access to foreign technology and foreign management methods. It was anticipated that these acquisitions would boost the Chinese economy and bring improved living conditions to the Chinese people. It was also anticipated that by encouraging Chinese scientists to study and work abroad, it would lead to an inflow into China of foreign knowledge, technologies and organizational and management practices. All of this has happened, and on a scale which was scarcely imaginable fifteen years ago.

During these fifteen years, not only has China changed, but so too has the rest of the world. These changes have led to increased globalization not only of economies, but also of science and technology. International collaboration in science is increasingly the way in which science is practiced, and the cost of doing research has meant that international collaboration is also necessary for cost sharing reasons. Technological collaboration within business cooperative arrangements is also becoming increasingly global. Multinational corporations frequently do their research in a first country, design in a second, development and production in a third, and initial sales in a fourth. Unless a country has technological assets which enable it to be an attractive partner in this globalization, it will become increasingly isolated.

China clearly has many scientific and technological assets, it has embraced its open door policy and has paid much attention to the encouragement of international collaboration. Nevertheless, the M ~~mission~~ formed the impression that there is not an explicit policy in China for international collaboration in science and technology which fully embraces the inmplications of today's global realities in technological development.. Given the subject's importance, China could consider convening a small international conference on national strategies for international collaboration in science and technology. This would be a way of learning about other international experience on an issue of major significance for China. X

The Lack of Clarity - even Ambiguity - in some Policy Pronouncements;

We discuss briefly in Part 2 of this report the use of 'eight character slogans' to convey the essence of policies - a practice whose result is to allow considerable freedom for interpretation to those decision-makers who are willing to be entrepreneurial and innovative.. One such slogan, ***"wenzhu yitou, fangkai yipian"*** informally translated by the Mission as *"anchor one end securely, let the other ~~side~~ free"*, is just one example of a policy statement which is subject to many interpretations.
roam

The Mission recognises that these phrases are designed to express in a concise fashion the essence of longer policy statements which they accompany. Additionally, these phrases can be seen as setting 'boundary conditions' within which a good deal of experimentation can take place. This stimulation of local experiments has, in fact, been one of the strengths of the Chinese approach to Reform.

S&T POLICY ISSUES CURRENTLY BEING DEBATED IN CHINA

The Problem of Duplication and Lack of Coordination

With China having literally thousands of S&T Institutions, it is not surprising that there is duplication of effort throughout the system. The question now needing to be addressed is that of duplication within a 'socialist market economy'.

On the one hand, a competitive system among enterprises in the future will ensure that a variety of common problems are attacked from a variety of competing perspectives. This may lead to a superficial appearance of 'duplication', but the market , if allowed to operate, will weed out the unsuccessful.

However, a system of extensive duplication of effort in *governmental* institutions which have no tradition of cooperation one with the other is an expensive luxury which no country should afford. The mission has seen examples of extensive duplication of efforts among uncoordinated separate institutions, all funded by one level of government or another, which co-exist in close proximity to each other[1]

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1 In one Province we heard of efforts to coordinate some 42 independent institutes in a program of rural development with fairly specific interests.

Issues relating to Industrial Technology

Many of the policy discussions we encountered during our visit to China related to the application of the results of research in the commercial market. We therefore identify first an number of ongoing debates relating to industrial technology and attempt to highlight, where possible, policy issues which need continuing attention as part of the ongoing process of S&T reform.

The Introduction of a 'Technology Market' and of Competitive Sources for the Funding of R&D

An essential element in the move away from the 'command economy' of the past was to create a 'market' within which users of new technology would become important sponsors of its development. Government moved swiftly in the period between 1987 and 1992 to inject R&D institutions into this technology market by

1 substantially reducing their core budget appropriations from government (in some cases, especially in the provinces, this reduction was to zero),

2 by making government contract funds, allocated by competition, an increasingly important vehicle for the promotion of technological development, and

3 by providing incentives for enterprises to invest at an increased rate in R&D.

This market discipline has had the positive effect of allowing creative institutions to expand their incomes and activities and to have substantially increased impact on the economy.

Not surprisingly, many enterprises were slow to respond and this has created great difficulties for most R&D institutions. Many enterprises are either unwilling to pay for technology which, in the past, they would have received without charge, or seriously undervalue technology which has been on offer from R&D institutes. (Similar experiences have been observed in the industrialised countries.) This example of 'market failure' has been influential in causing a number of R&D institutions to transform themselves into enterprises as a means of commercializing their own technologies.

The ~~mission~~ M found that the entrepreneurial scientists and institutes whom we met were very much in favour of these reforms, since it had given them the opportunity to increase the resources available for their work, while some of those who had been less successful in the competitive arena were less enthusiastic. In some provinces, there appeared to be a growing belief, even among successful provincial institutes, that only national institutes could win support from some of SSTC's programs (such as 863 or the key technologies program). In other regions of the country, we did not encounter this view. It would be worthwhile for SSTC to undertake periodic reviews of the institutions who are ~~in~~ competing for national funds, to be assured that decisions are made on the technical merits of proposals and not simply on the organizational status of the group applying.

Chinese experimentation with the concept of a 'technology market' may well lead to some distintive features in what we refer to as China's 'national system of innovation'[2]. One critical question in any market is that of minimizing the 'transaction costs' of interactions between organizations (eg enterprises, research institutes) which have to deal one with the other. Can an appropriately designed policy environment facilitate low-cost interactions among enterprises and suppliers of new technologies? Some continuing attention to this issue could be beneficial to creating a positive climate for innovative activity.

The Emergence of Spin-off Enterprises

A very common response of R&D institutions to the new market conditions has been to create spin-off enterprises in attempts to commercialize technologies which they have developed. Very large numbers of these enterprises have been created (The Chinese Academy of Sciences informed the mission that the Academy and its 123 Institutes had created 900 such spin-offs!) and their rate of success appears to the mission to be similar to that in the industrialised countries - that is about 1 or at most 2 in 10 are very successful, 2 or 3 can survive in the longer term without much expansion, and the rest fail. However, the present policy in China does not allow these failed enterprises to go out of business since this would create problems concerning the social welfare of the employees involved. Vigorous debate on economic reforms, as it touches on the problem of bankruptcy, is continuing with, as an example, researchers at the Economics Research Institute of the Chinese People's University in Beijing arguing that "Poorly operated enterprises should be allowed to go bankrupt so that inefficiently used funds can be freed to be injected into profitable enterprises"[3]

Responsibility for continuing to subsidise unsuccessful spin-off enterprises appears to reside with the parent institute. If China is to develop a successful socialist market economy in which new, high technology enterprises play an increasingly important role, the Mission believes that it will be necessary to proceed speedily to resolve the question of a new social welfare system and to permit the process of bankruptcy to occur.

Imported Technology

We are aware that China has imported very substantial amounts of foreign technology in recent years, particularly through the program of technological renovation of enterprises. In some enterprises which we visited, there are vigourous programs in place to assimilate those technologies into the fabric of the receiving enterprise's production system and to build on this technical basis. We have heard of specific cases in which enterprises may spend as much as three times the purchase price of foreign technology on programs to master, adapt and build on that technology. We are however not

2 defined in the next section of this Part of the Mission Report

3 Cited in the China Daily, Tuesday July 4, 1995, p4 in an article headlined *"Put Money into Fittest Operations"*

in a position to judge how widespread is this practice, particularly among state-owned enterprises, but other evidence suggests that it is not common. For example, the Science and Technology Commission of the Chinese People's Political Consultative Conference contends that

> *The funds for digestion, assimilation and innovation are seriously inadequate. In Japan and South Korea, the expenses for digestion and assimilation are much higher than that of introduction of technology, but in China, on the contrary, when 1.00 yuan is spent on introduction of technology, only 0.09 yuan is used for digestion and assimilation, and in Shanghai it is only 0.07 yuan*[4]

We believe that future reforms should look for means to encourage investments in mastering and building on imported technology.

Organizing for Technological Innovation within Enterprises

Although the Mission heard much comment about the need to invest in R&D within enterprises, we heard little debate about how this R&D capacity should be organized. Also, as the comments of the Science and Technology Commission of the Chinese People's Political Consultative Conference reported above underline, while a minority of enterprises have recognized the need to invest resources to properly absorb and master imported technology, many have not. In the opinion of the Mission, these two issues can be interrelated in important ways.

In the industrialized countries, many large corporations have recognized that there are two types of technical change. One is radical technical change which usually requires formal R&D laboratories, but the other is incremental technical change which may sometimes involve a formal R&D organization, but frequently is introduced by teams of specialized engineers who work close to the production units. Sometimes it is the production units themselves who introduce these incremental changes. The specific way these incremental technical change units function varies from enterprise to enterprise and from industry to industry.

The Mission is aware that some industries and enterprises in China are cognizant of these issues. For example, the Chinese National Offshore Oil Corporation worked with a UK research group a few years ago to understand the process of innovation in UK offshore drilling companies. However, we formed an impression that, over the past five years or so, the majority of Chinese enterprises which have imported technology have done so without investing in the activities necessary to absorb and assimilate that technology. The experiences of successful corporations in the industrialized countries in assimilating imported technology and in organizing for both radical and incremental technical

[4] See Science and Technology Commission of the Chinese People's Political Consultative Conference *"The Problems and Proposals Concerning Technological Progress in Large and Medium-sized State-owned Enterprises"*, Forum on Science and Technology in China, Vol 1 No 1, June 1994

changes may be worth investigating by Chinese enterprises and policy makers.

One point worth emphasis relates to the importance of enterprise strategies to promote technical change. It is important for enterprise managers, operating in a global market context, to understand the limitations of what governments can do for them, and the crucial roles which they, themselves, will play in determining the technological success or failure of the enterprise for which they are, ultimately, responsible.

Protection of Intellectual Property

The Mission has found that an increasing number of Chinese institutions are beginning to see the practical benefits of a system for the active protection of intellectual property. Some institutes have already had to prosecute employees for making unauthorized transfers (typically to township or village enterprises) and have found some difficulty in the courts in having the legal system understand the basis of their case. In other cases, spin-off enterprises have had to be careful about the ownership of the technology which they take into international markets. As China moves progressively into global markets and moves to freeing trade domestically. it will need to ensure the adequacy of its system for upholding the property rights which its legal system confers.

The issue for China to consider is that of the adequacy of the present system of implementation of its Intellectual Property Legislation. A recent World Bank document argues that, among the remaining challenges (of S&T reform) facing the government of China, there is "Intellectual property rights enforcement" and it suggests that

> *The key concern is how effectively intellectual property legislation is and will be enforced. The key tasks ahead involve raising awareness of intellectual property rights, among users and providers of technology, fostering the further professionalization of enforcement personnel, and ensuring that these rights. are adequately pursued. A nationwide professional; court system is needed, exemplified by the recently created Intellectual Property Courts dedicated to enforcing the IPR regime. Education and dissemination seem to be key to improved enforcement in the short term.*[5]

High Technology Development Zones and New and High Technology Enterprises

China now has 52 High-Technology Development Zones, spread across the country, within which a variety of national and provincial incentives operate to encourage the development of new, high-technology enterprises. There are currently estimated to be about 55,000 'approved' new and high

[5] See World Bank Report #12814-CHA, "Staff Appraisal Report-China-Technology Development Project" Washington, January 18, 1995

technology enterprises (NTEs) located in these zones.

Some of these zones, in provincial cities, are still small but others, such as the one in Pudong Development Area in Shanghai, are very large. Additionally, China has several other categories of zones within which enterprises are eligible to receive preferential treatment (eg the Pudong Development Area consists of a Finance and Trade Zone, an Export Processing Zone, a Free Trade Zone and a High Technology Zone, all of which seem to be competing to attract the same enterprises, and each having a similar set of incentives available)

According to a draft report from the CAS Science Policy and Management Research Institute[6] there are five important sets of issues relating to these new zones and the companies which operate in them. The issues relate to X

6 points here

- *the ownership of the assets of NTEs*, most of which have been created by R&D institutes and other public bodies; in the absence of a fully-developed share-holding system, the ownership of the assets of many NTEs can be in doubt;

- *the modernization of the management of many NTEs*;

- *the precise delimitation of the roles of the management authorities of the new high-technology development zones* - do they constitute a new level of government? or are they regulatory agencies (determining the eligibility of individual enterprises claiming the incentives offered by the zones?) or are they support systems, designed to help NTEs through the early stages of enterprise growth and development?

- *the treatment, from an incentive view-point, of enterprises within a zone which expand their production in facilities outside the zone;*

- *the eligibility of NTEs to compete for further national support through a variety of funding channels;*

- *the development of adequate systems of taxation administration, financial management, accounting and auditing, both for NTEs and for the zone management authorities.*

The Mission saw evidence in one province, Guangdong, of an apparent concentration, in the Pearl

6 See Fang Xin, "*Analysis and Evaluation on the Management System of Science and Technology of China*" CAS Report no 3 of the "Evaluation on the Strategy of Science and Technology Development of the Chinese Government", Beijing, (undated)

River Delta, of high-technology parks and zones, some 'national' and others 'provincial'[7] and of plans to create a much more extensive "high-technology belt" The subtleties in the distinctions among "zones", "parks" and "belts" were never satisfactorily explained to the Mission

Two points can be made from international experience which may be relevant to the future development of high-technology zones.

First, in the industrialised countries, there is a growing appreciation of the effects of geographic clustering of complementary industrial competencies. In a world in which 'globalization' is increasingly perceived to be the driving force behind enterprise strategies, and where national boundaries seem to be less and less significant, it is also becoming increasingly clear that the competitive success of many enterprises is due to ***localised*** concentrations of skilled people and technologies. To the extent that China's High Technology Development Zones can produce focused concentrations of skills and technologies, and can promote cooperation among the enterprises located within those zones, they may in fact be important contributors to the competitiveness, in global markets, of those enterprises which have the managerial capacities to succeed.

Second, on a less positive note, as China moves to join the World Trade Organization, it should look at the treatment by the WTO of 'subsidies' to R&D. The kinds of incentives given within specified geographic locations (and hence not open to enterprises located elsewhere) may be deemed as unacceptable to the WTO and, as such, could render products produced in the zones vulnerable to countervailing tariffs. It is by no means clear, at this point in time, that this would in fact be the case, but Chinese authorities should be attentive to this possibility.

Transfer of Military Technology for Civilian Use

China has had a policy of encouraging the transfer of military technology for civilian use for 15 years. A recent White Paper on Arms Control and Disarmament (November 1995) has revealed just how extensive the transfer has been. More than 15,000 products for civilian use are produced by defence establishments. These include 60% of all motorcycles, 9% of all automobiles and 24% of all mechanized coal cutting equipment produced for civilian use in China. X

The Mission visited one military R&D institute (the Northwest Research Institute of Electronic Equipment) which is producing satellite antenna for the civilian market. This establishment had moved from a secret location in the mountains to Xian in order to take advantage of the preferential tax incentives offered by the High Technology Zone. It marketed its products both nationally and internationally. Profits from the civilian production are plowed back into the civilian work, and, in practice, part of its revenues help finance some of the huge social costs which the Institute carries.

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7 According to provincial officials the incentives in a 'national' zone are 'somewhat better' than those available in a 'provincial' zone.

The policy issue of interest to the Mission was whether the Chinese approach of transferring technology to civilian use by means of defence establishments manufacturing civilian products is the best approach. International experience has taken a different approach whereby military technology is transferred to civilian enterprises. In this way, military R&D establishments continue as R&D establishments and rarely get involved in production. Civilian companies manufacture ~~armaments~~, military and/or civilian products. In the industrialized countries it is believed that the civil enterprises, with management systems in tune with the market place are better placed to manufacture products for that market place than defence industries who have usually operated on a cost plus basis.

The ~~m~~Mission recognized that without changes to the social welfare system, the current Chinese approach is probably the most sensible one. If social reforms make it possible to humanely shed staff, then it would be worthwhile for China to study the foreign experience of technology transfer, and the foreign experience of developing dual-use technologies, i.e. technologies which can be exploited for both military and civilian uses.

Product Design and Quality

China is no longer shielded from competition and its products and processes must be able to compete with overseas technology both on the Chinese domestic market and in global markets. Programs to upgrade product design and quality, and to improve market intelligence, should be features of the next round of S&T Reform. We believe that first steps in this direction are being taken within a World Bank Project[8] on Technology Development. Attention to industrial design and participation in international quality assurance schemes such as the International Standards Organization's ISO-9000 Program should be increasingly seen as desirable options for enterprises participating in China's programs of Technological Revitalisation and S&T Reform.

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Issues relating to Basic Research

A second set of issues which we encountered related to the future of 'basic' research in China.

Some Questions of Definition and their policy implications

In the industrialised countries, the phrase 'basic research' has come to embody a whole range of activities, including:

[8] World Bank, *op cit*

- so-called ***'curiosity-oriented' research***, often, but not always, carried out by individual scientists, searching for general scientific understanding rather than seeking to contribute to the solution of some pre-identified social or economic problem. Such research encompasses whole fields of science, such as cosmology and astronomy, as well as being practiced at the boundaries of knowledge in other field in which the mainstream is already linked to application. The research supported in general shows little likelihood of contributing to economic development in any foreseeable time-frame. This type of scientific activity is giving rise to growing numbers of informal international networks of collaborating individuals and groups, their collaboration being facilitated by the inexpensive availability of electronic communications. The activity also provides a useful opening into the global scientific community.

  In the industrialised countries, this mode of undertaking research is widely seen as a good vehicle for the training of new generations of researchers, since it provides ample opportunities to young scientists to learn the skills of research. Many academic programs, and qualifications, still demand that the candidate undertake an individual piece of original research, and so large numbers of graduate students are the hallmark of successful programs of this type.

- ***strategic research***, where teams of researchers, frequently from a variety of disciplines, explore the frontiers of knowledge in broad areas of science which are believed likely to be of future importance to economic or social importance; in this domain, the probability of some application is thought to be foreseeable in the medium term, even though the specific route to application at this time might be far from evident.

  This form of research is becoming increasingly important (but should never replace curiosity-driven research in its entirety) and is posing new problems for institutions of higher education who have to conceive of new ways of evaluating the work of graduate students who work in teams rather than alone and who work in new transdisciplin~~s~~ry areas rather than within the confines of a traditional academic discipline.

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- ***'Big Science'***, of two kinds: first, that science, such as high-energy physics, which requires ultra-expensive facilities; and second, the geographically extensive research needed to understand changing global environmental phenomena. Both types of 'Big Science' are increasingly affordable only by consortia of countries who are prepared to share the considerable costs involved

We believe that policy options for the support of basic research in China would become more easily defined if the debate was to identify appropriate approaches, in the Chinese context, to each of these three rather distinct activities. In particular, we see the National Natural Science Foundation as the appropriate body to finance 'curiosity-oriented research' since it is able to apply high standards of peer review to individual projects. We will discuss later in this Part of our Report some options which we see for the support of strategic research (and the closely allied subject of 'pre-competitive research'), and in Part 2 of our report we have a few comments to offer on future support of 'Big Science'.

What about 'pure' research & "fundamental", 'academic & academically related'

Preservation and Encouragement of 'Basic research'.

Since the 1978 National Conference on S&T, China's S&T Policy has always contained explicit support for basic research and this is equally true of the May 1995 Decision on Accelerating Scientific Progress. (However, many people would point out that the earlier declarations of support for basic research, frequently, were not carried through to actual resource allocations) We have, however, heard of, but been unable to quantify, an emerging problem in the basic research system which will need to be tackled in the Ninth Five-Year Plan. Apparently large numbers of the best of China's science graduates are being attracted to the higher incomes available to them in high-technology enterprises or in joint ventures, and so, it is argued, fewer and fewer of them are choosing careers in basic research. We know that there are programs at the national and provincial levels to attract 'young stars' into research, including basic research. We would suggest that it will be important to evaluate the success of these programs on an on-going basis, to ensure that an appropriate share of these younger talents continue to choose careers in basic research.

While much attention in this report, and in China, is devoted to seeking improved means of articulating China's investment in basic research with the longer-term economic and social needs of the country, we agree with many of our Chinese colleagues who wish to retain three other important roles for basic research in a contemporary society. These roles are

1 as a vehicle for advanced human resource development;

2 as a means of building a national knowledge base - a kind of social intelligence function - which equips a society to react to the uncertainties of a rapidly changing world; and

3 as an expression of national culture, in which knowledge is valued and the search for new knowledge is appreciated.

In all three of these roles, we agree with the emphasis placed by China on the importance of international collaboration - for all countries.

The Continuing Reform of the Chinese Academy of Sciences

The process of reform has been on-going within the Chinese Academy of Sciences for a decade or more as the Academy seeks to redefine the role of its extensive system of 123 research institutes. (The Academy's role as an honorific association of leading scientists is not challenged.) From a body which in the mid-1980s was almost 100% financed by an unconditional annual budget appropriation, the Academy now sees its revenue sources diversified with its annual income of about 1.4 Billion yuan coming

- 20%, as a budget allocation from the national government;

- 30% by contract from national ministries;
- 30% by contract from enterprises, and
- 20% by contract from provincial and municipal governments

According to the Academy, the CAS has evolved away from an old Soviet model of an isolated set of basic research laboratories with no real contact with either universities (which, pre-1978 did little research) or with enterprises into a system of national laboratories designed to

- ☐ provide a national base of competence in basic research, across the natural sciences, in a series of increasingly 'open' laboratories which host visiting scientists from across China and across the world (this includes CAS' special responsibility for China's activities in 'Big Science');
- ☐ provide advanced training to talented young scientists;
- ☐ participate in developing the most advanced high-technology sectors of Chinese industry; and
- ☐ undertake research which is broadly defined to be in the public interest (such as environmental science)

The CAS has developed a 'vision' of its own future which would see its workforce decline substantially from its present 50 000 scientific workers[9] (out of a total of 90 000 employees), operating in a 'one academy, two systems" mode in which selected basic research competence would be maintained using the government supplied budget, and an increasing share of the workforce would undertake applied tasks, financed by external sources.

As with all such large and previously dominant institutions, CAS has many critics, and we met groups who cite the May 1995 Decision of the State Council as meaning that basic research should be done in the universities and applied research in enterprises - leaving little space for the CAS institutes (As we set out in Part 2 of our report, the Mission does not subscribe to this oversimplified interpretation of how to implement the May 1995 Decision) Additionally, we heard again the often -asked question as to why the CAS is engaged in agricultural research, given the existence of Academies of Agricultural and Forestry Sciences and given CAS' apparent remoteness from any extension services.

The Mission believes that there is great scope for the CAS to take the lead in defining new and productive relationships with the universities in its activities in fundamental science and with enterprises in the more applied aspects of its work.

The debates surrounding the CAS and its future should be seen, the Mission believes, as only part of a necessary, and much wider, debate on the restructuring and rationalization of the overall system of R&D institutes in China. Once there is in place a national social security system capable of coping with redundant workers, the reform of many Chinese institutions will need to be undertaken as a matter of urgency.

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9 We heard one suggestion that it should decrease to having only about 12 000 scientists on staff

Refer to international experience of transformation of govt enterprise R&D - from Korea to Australia to Canada.

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The Continuing Reform of the Research Role of Institutions of Higher Education

The range of research competence in China's more than 1 050 universities is truly great.

At the top, some of the elite universities have wide competence across many fields of inquiry and their scientists do well in national competition for funding. For example, from data provided to us by The State Education Commission and by the World Bank, of the two hundred and one special institutions for research (State Key Laboratories, State Education Commission Laboratories, and Engineering Research Centres) now in place or whose establishment has been approved, a remarkable 100 (or 49.8%) are located in only eleven universities - Tsinghua (20), Beijing (14), Xi'an Jiaotong (9), Huazong University of S&T, Shanghai Jiaotong and Tongji (8 each), Fudan (7), and Nanjing, Jilin and South East University (6 each)

More broadly, we were told that some 200 universities have the right to grant Ph D degrees and that 400 could grant Masters qualifications, but we suspect that in the majority of these institutions, the right to grant such degrees is probably limited to a few specific departments.

International experience suggests that doctoral level training requires that the departments which offer Ph.D. degrees must themselves be heavily involved in research. The same is not necessarily the case for undergraduate or masters level programmes. This would suggest that priority should be given in China to ensuring that all of its university departments which are authorized to award doctoral degrees should become thriving research departments.

Scientific & Technological information

The Mission did not visit any of the organizations in China which specialize in the collection and dissemination of scientific information. Our views on this topic are therefore based solely on impressions gained from our discussions with policy makers and scientists. The impressions suggest:

* Although some research centres have very little problem in accessing western scientific and technical literature, it remains a major problem for most institutions. The only institute which claimed to have no problem in purchasing western journals was the military research establishment in Xi'an.

* The issue of publication of scientific papers in Western or Chinese journals seems to be a hotly debated one. Those in favour of publishing in Western journals argued that this enabled the Chinese research to be internationally peer reviewed and helped ensure that Chinese scientists maintained international standards. Those in favour of publishing in Chinese journals argued that their own journals were read and understood by many more Chinese scientists than had access to Western journals. Also if the best papers were published overseas the quality of the Chinese journals would decline.

Issues of national prestige and the ~~ability~~ possibility of individual scientists to be listed in the Science Citation Index also featured in the debate. The Mission recognized the strength of the arguments in both sides of the debate. English is the international language of science and as long as China seeks to be a part of the international scientific community then its scientists will be disadvantaged if they are unable to communicate in English. On the other hand at this stage in its development, China needs to disseminate its scientific knowledge widely within China, and this means using the medium of the Chinese language.

* Beyond formal publications, much scientific and technical knowledge is disseminated in Western countries through what is called 'grey literature', i.e. literature and reports which were originally distributed among networks of colleagues without being formally published. This practice has been largely replaced in recent years by the dissemination of information through the INTERNET. In China we gained the impression that such informal reports are rarely distributed and shared. Information seems to be held 'secret' by a department or agency and there is a reluctance to share this with others. This impedes the dissemination of knowledge.

* The use of INTERNET is not yet widespread in China, but its benefits are well known and understood. Several of the scientists we met in Eastern China have E mail addresses. We anticipate the use will spread quickly and this could have major impact on the diffusion of information, and perhaps facilitate greater research collaboration. The access to the World Wide Web will also have implications for the further opening up of China to Western values and culture, not all of which are likely to be beneficial to China.

Underutilization of Scientific Societies

The Mission heard of the desire and capacity of many scientific societies in China to play a greater role in the scientific and technical life of the new China. Only the Chinese Medical Society appears to have been accorded any significant operational role (in this case in the screening of drugs and in the assessment of research directions and of the quality of some applications for funding). It could be useful for SSTC and the Chinese Association for S&T to discuss opportunities for the greater involvement of the scientific societies in the reform process.

Popularisation of Science and Technology

& improve

In the early 1960's the Chinese government invested substantial resources to popularize science and technology (or the public understanding of science and technology). Its reasons for doing this were in part to diffuse the scientific method of combining theory with practice in finding solutions to problems; to show that there were scientific explanations for phenomena previously explained by superstition; and to diffuse scientific and technical knowledge. At the same time, the value of traditional knowledge was recognized and considerable efforts were made to integrate traditional and modern knowledge.

as evidenced by

Now more than thirty years later, the state of public understanding of science is still an important policy issue, and for exactly the same reasons as in the earlier period. However, whereas most of the efforts of the industrialized countries focus on popularizing science per se, the Chinese approach also recognizes the importance of spreading knowledge and understanding about how science and technology effect peoples lives.

The Mission believes that this is an important policy area for China and regrets that it did not learn more about the current programmes.

Issues relating to Resource Use

Environmental Protection: an example of the problems of implementation

China faces environmental problems in its air, water and land resources of staggering proportions. Air pollution is a health concern in many industrial and urban areas: smoke and dust emissions are reported to be rising by 7% per year; sulphur dioxide emissions are expected to rise to 23 million tons annually by the year 2000; acid rain is becoming more widespread. Water sources are also in a state of crisis in many parts of the country: more than 40 of the largest cities are facing water shortages; a 100 million tones of waste water is produced a day leaving some rivers dangerously polluted. Limited resources are threatened by desertification, which is reported to reduce stable land by 2,100 square kilo metres annually, and by industrial solid wastes of 250 million tones a year by 2000, as well as widespread impacts on soil quality through chemical fertilizers. Unless these trends are reversed, China is expected to become the largest single producer of both carbon dioxide, the leading cause of global warming, and sulphur dioxide by the next century.

The problem of how to improve environmental protection while maintaining economic and social development is clearly a major policy issue at all decision-making levels in China, and the Mission was impressed with the concerns expressed and the initiatives underway. The National Environmental Protection Agency (NEPA) are collecting statistics on the equally staggering costs to the economy of environmental degradation. which add up to a total of some 100 billion yuan annually.

The main approaches being developed for protecting the environment are:

- tough new environmental legislation (including even the death penalty),
- imposing fines to pay for pollution measures through a polluter pays" policy
- environmental assessments and more stringent standards for new industries and development zones,
- investments in cleaner technology, land rehabilitation and reafforestation projects,
- major infrastructure schemes for energy development and water transfers, and
- improving public environmental awareness and education.

The government has strengthened its environmental monitoring and enforcement capability. By the end of 1992, a network of 1,808 monitoring stations had been established under the authority of national, provincial, county or town administrations with a total staff of more than 25,000, and more than 16,000 staff are employed in environmental regulatory agencies.

Over the last decade China has put in place a comprehensive environmental management system. Why then did the Mission hear such concern about implementing environmental protection measures? The issues seem to relate to

a) the regulatory system for pollution control
b) the pricing system for resource inputs (particularly low prices for energy and water, which lead to inefficiencies and waste) and
c) the environmental impacts of other economic and social policies.

In terms of policy reform, it is easier to adjust environmental regulations than either resource pricing (see **Resource Pricing**) or broader economic and social policies (see **Impact of S&T Reform on Rural Development**).

Current debates about environmental regulatory policy

- pollution charges are too low: it is cheaper for polluters to continue to pay than to clean up:

- a polluter only pays for the worst-offending pollutant: there are no incentives to educe emissions of other pollutants

- fines collected are not invested into shared treatment facilities which can be more cost-effective e.g. for waste water treatment

- although they account for an increasing proportion of the industrial output of the country, the millions of township enterprises are relatively little regulated because regulatory effort has focussed on the 3000 largest enterprises which produce 60% of China's industrial emissions.

International Experience

China has already adapted international experience in standard setting and monitoring to its own situation. In some respects, such as the allocation of revenues from pollution fines to local funds for distributing to enterprises as subsidies or soft leans to finance cleaner production technology, China is an innovator. Future policy reforms under consideration in China have been trod in a number of OECD countries: these include pollution charges which are high enough to encourage firms to invest in cleaner production technology and a more integrated system of economic instruments, including not only pollution charges, but taxes, tradable emissions and subsidies.

Resource Pricing

One of the emerging policy debates in China is that of resource pricing. The Mission was told that, in general, the prices of energy and water inputs are much lower than the real cost of supply and that this leads to resource inefficiencies, overproduction of wastes and increased pollution. The Mission would suggest an even broader policy debate would be timely on the development of a natural resource accounting framework, and measuring the value to the national economy of environmental goods and services. China's environment provides not only all its natural resources but also waste management services as the means of diluting, absorbing and removing waste products through air circulation, stream flows and biogeochemical cycling. In addition, biodiversity has an immense value to the Chinese economy, as a source of genetic material for improved food species, and as a source of new products and pharmaceuticals, as well as added value to the tourism industry.

It is generally recognized that official coal and water prices are far too low in China. This has negative repercussions in the case of coal mining, because low coal prices discourage coal mines from investing in environmental protection or safety measures. The recent expansion of township enterprises into coal mining has exacerbated the environmental damage caused by the mines themselves. More generally, the low price of energy provides a perverse incentive to industry to pollute.

The total (economic, social and environmental) costs of coal include not only the mining costs, but also transportation costs from the north and west of China to the populous east and south. Currently, 40% of China's railway capacity is reserved for coal transportation, but transportation is a main bottleneck to supply as well as incurring additional pollution costs. Water washing coal would reduce the amount that is transported at well as the ash produced during burning, but in 1985 only 16% of all raw coal was washed compared to 80% in OECD countries. ~~In addition, coal incurs costs of being converted into electricity~~.

The policy debate is a complex one, going far beyond the acceptance that the price of energy be increased into a broader examination of alternative policy instruments, from pollution fines, to consumption taxes and tradable permits The costs of coal, for example, could be increased at the mine head, by requiring mining enterprises to pay a levy for the costs of environmental damages caused by extraction. Reforming the transportation component in the cost of coal would inevitably involve a wider consideration of freight rates and regional inequalities in terms of distance from energy users. Incorporating the total costs of energy consumption into the price to consumers would involve a policy equation that includes comparisons of the locational advantage of sites for power production, and local environmental quality standards.

Similarly, for water, the low prices that farmers receive for grains means that they cannot pay higher prices for water. The environmental result is that they waste water, but the policy reform needs to encompass not only water pricing but also grain prices.

An analysis, conducted for the China Council, of 1993 water prices in Beijing showed that to recover the total costs for supplying water in Beijing, prices should be 10 times higher for industrial users, 15 times for municipal users, and 77 times higher for agricultural users. If prices were raised sufficiently to reduce current waste (over 50% of water in Beijing is still used for agriculture) so that the huge costs of the Eastern Route Water Transfer project could be delayed even by a few years, the savings would be enormous.

The Mission believes that the resource pricing policy debate is a very important one for the science and technology community in China to address. It is also evident that any policy reforms will need to go far beyond science and technology and encompass broader economic and social reforms.

Rural Development

During the decade 1985-1995, S&T reforms have contributed to the great changes taking place in the Chinese countryside but they have done so in a broader context of social and economic change. A number of national goals have guided S&T reforms for rural devdopment:

- national food security, especially sdf-sufficiency in grains;
- low food prices and food availability for the poor;
- increasing agricultural productivity, as land per capita decreases;
- increasing rural incomes and rural employment;
- transforming agriculture from a subsistence to a commercial basis;
- maintaining rural society by reducing the rural-urban prosperity gap.

Eighty percent of women live in rural areas and 70 percent of the adult illiterate population are women. In atdition to the goals listed above, increasing the access of girls and women to education, and to the benefits of science and technology, as well as strengthening their participation in economic activities, are clearly critical to rural development.

Two groups of S&T reforms have had great impacts in rural areas; these are the priority given to agricultural research and the contribution of the Spark program to the rapid development of rural industries. Both groups of reforms have brought both successes and new challenges.

Agricultural productivity

A key goal has been to apply science and technology to raising agricultural productivity. This led to some early successes; for example, the net results of technological improvements and the changeover to the family farm led to an increase in grain productivity of 43 % between 1978-84, and for wheat, the percentage increase in yields for the same period was 61%. These spectacular trends have not been maintained, although further technological developments have taken place in improved genetic varieties grown and in the use of chemical-intensive production methods. It has been estimated that agricultural chemicals have accounted for about 30% of the the increased grain production since the

1970's and have reduced the labour required per hectare. Despite this, there is both a low efficiency in the use of fertilizers compared to other countries and widespread environmental contamination because of heavy chemical loads in soils and water bodies receiving agricultural run-off. The costs of inputs, such as chemicals, have increased more rapidly than the prices paid to farmers for their outputs, especially grains.

The Mission was told that there is concern about the dependence of Chinese agriculture on chemical inputs, both because of their cost, and their negative impacts on the environment. There are renewed calls for a new agricultural transformation, based on biological pesticides and organic fertilizers, as well as on plant varieties that are drought-resistant and are adapted to more marginal land. These are priorities for S&T investments. However, we were also told that the present combination of economic and technological developments have created a situation in which farmers are discouraged from growing grain and are turning towards other, more profitable, activities such as growing alternative crops, including vegetables; working in township enterprises or migrating to urban areas. These are issues that clearly go beyond the domain of science and technology.

Rural enterprises

A major contribution of S&T reforms to rural development has been the Spark Program. This successful combination of packages of proven technologies with an effective delivery system, including extension and demonstration projects, has been hailed as a major success story. The Mission was impressed with the examples of projects that we visited, both those focussed on agricultural post-harvest storage and processing, and those less directly based on agriculture. The Spark Program has shown that science and technology can be packaged to benefit the lives of the rural poor, and other countries could benefit from a close look at the Chinese experience. It was not clear to us how far the Spark Program included specific consideration of the needs of rural women, and indeed, whether it has led to greater benefits for men than for women. It clearly has potential to improve the status of rural women through increasing their incomes and their participation in rural enterprises.

The proliferation of rural enterprises has become a greater generator of rural prosperity than agriculture itself, and this has led to some of the problems noted above. Between 1980 and 1989, the contribution to rural productivity (in thousand million yuan) of agriculture went from 192 to 653 (a percentage increase of 240) and for rural industry from 54 to 589 (a percentage increase of 991). The rural enterprises have created employment for the increasing numbers of rural surplus labour, but they raise concerns about health and safety at work, as well as contamination of the rural environment. They also serve to reduce the attractiveness of agriculture, which is still the key to China's future economic prosperity.

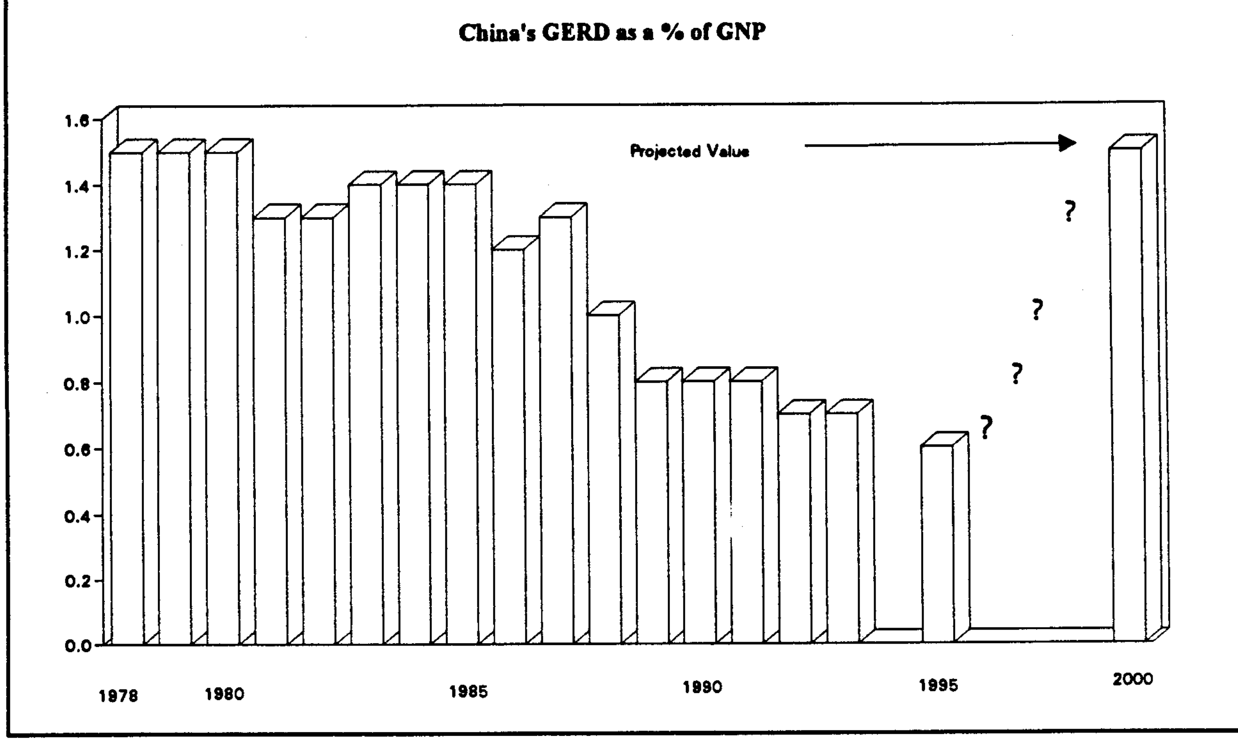
Future Reform of Agricultural R&D

The national and provincial agricultural research and development institutes have appeared to be slower in taking advantage of the opportunities presented by reform, and the development of an effective technology market for much of their research output has been slow. The reasons behind these observations, we believe, lie in the inexperience of the research staff in dealing with technology market conditions, and the reluctance of end-users to pay for technology and consulting services which have been provided at no charge in the past. The scope for more effective technology transfer is improving with the growth of rural enterprises which are providing a new market for S&T, and whose needs, especially in the areas of post harvest and food-processing technologies. This new demand should help to initiate the necessary changes in the research programs and priorities of the agricultural institutes.

The urgent challenge facing policy-makers concerned with the improvement of S&T activities in the agricultural sector will be to restructure the existing research service to make it more relevant and efficient and more capable of responding to the urgent needs of the rural sector in the next decade and beyond.

Issues relating to the Financing of S&T Activities

A Target for R&D Spending for the Year 2000



The May 1995 *Decision on Accelerating Scientific Progress* contains an ambitious target for the growth of China's Gross Expenditure on R&D (GERD). It is proposed that GERD be increased, in a five-year period from its present value of between 0.6 and 0.7% of GDP to the target of 1.5% of GDP, with enterprises accounting for 60% of the target and with the governments of 'economically developed regions' expanding their expenditures at a higher than average rate.

The Mission believes that rapid consideration needs to be given to the adequacy of the existing array of fiscal and tax incentives currently offered to promote R&D activities within enterprises if the government is going to be able to convince enterprises to change their behaviour. Some consideration might be given to general tax incentives for R&D activities such as those offered in some industrialized countries (such as Australia or Canada). An addition route to increasing R&D funding worth exploring could be the imposition of levies on production, a system used to good effect in supporting agricultural research in many countries.

An additional factor which needs to be taken into account is the influence of the rate of inflation on the decision-making behaviour of enterprise management. In the industrialized countries, periods of high inflation appear to induce a stance of "risk-aversion" in many enterprises who usually take a conservative view of investments in R&D during such periods of economic uncertainty. Conversely, periods of rapid expansion of industrial R&D expenditures tend to appear in periods of low inflation. As a consequence, the attainment of the goal on S&T spending may be highly dependent on China's macroeconomic performance between now and the end of the decade.

EMERGING ISSUES

Intro IP.

Policy Advice

In the market economies of the industrialised countries, scientific research and technological development are widely distributed between the public and private sectors, among institutions of government, universities and enterprises. This has lead governments to seek advice on new policy directions from people engaged in all of these differing kinds of institutions as an input to decision making, which remains the prerogative of government. Each government has institutionalized the process of advice-giving in a form appropriate to its system, but all systems share in common the idea that senior political leaders should be able to receive such direct inputs into their work. As China's socialist market economy evolves, the Government of China should give thought to how it can tap into the growing experience of enterprises, universities and R&D institutes as it continues to evolve policies for the promotion of innovation and technological change in the light of the ever-changing global economic system.

The Need for Policy Integration

The countries of the industrialised world have now all accepted that technological change is a principal driving force within their economies. As a result, they have concluded that they need to pay special attention both to policies to promote S&T and innovation, and to the integration of the main elements of these policies into the other principal elements of their public policies in other fields. This has meant paying attention to the level of coherence which can be achieved among economic, trade, education, defence and other policies with those designed to promote technical change and innovation. The Mission did not get a clear picture of how this policy integration might be promoted among the main commissions which set policies at the highest level in each level of government (national, provincial and municipal) and would suggest that this is an area in need of some clarification.

We are aware of many interpretations of what will emerge to fulfil the proposal in the May 1995 Decision of the State Council to create "a leading state science and technology group....to strengthen overall policy making and management related to scientific and technological work throughout the country. Any such leading group could certainly help by looking into the question of policy integration.

Curiously-worded

Setting Research Priorities

The impression gained by the mission was that priority setting for research, both short term and long term, was set following debate among groups of scientists. This process is highly appropriate for priority setting within and between scientific disciplines when the choices depend on purely scientific criteria. This is the case for basic research. When priorities need to be set for strategic research,- that is research which might have economic and social benefits in the long term, - then a mix of scientific, economic and social criteria need to be used.

In recent years the more industrialized countries have developed quite sophisticated techniques to aid priority setting, in which criteria relevant to market considerations are integrated with scientific criteria. Governments have an important role to play in facilitating these priority setting exercises, although members of the scientific and business communities also play important roles in their conduct.

The term 'Research Foresight' is often applied to these activities and different countries have evolved techniques appropriate to their own domestic situations. The Japanese were early pioneers in the development and application of these approaches, but more recently the UK government has facilitated a major foresight study in Britain, and the South African government is about to launch a foresight study in South Africa. Australia has also developed some original approaches for research priority setting.

Given China's commitment to investing in research which will yield benefits to the Chinese economy and society within ten to fifteen years, the mission believes that some of these more sophisticated priority setting techniques might be usefully applied in China.

A 'National System of Innovation'

In the industrialised countries, the focus of policy development which is concerned with the role of technological change in the economy is now firmly on 'innovation policy'[10] and the concept of a 'national system of innovation' has evolved. While we have seen occasional references to innovation in Chinese policy pronouncements, it is our impresiion that China is still highly focused on R&D policy - an important subset of innovation policy, but not as comprehensive a concept. We believe that China should now turn some of its attention to the 'national system of innovation' mode of analysis as a means of identifying the future needs for reform in the S&T system and in the S&T system's relationship with overall economic and social activity in the country.

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[10] A useful and brief definition of "innovation" characterizes it as being "... *the transformation of an idea into a new or improved product introduced on the market or a new or improved operational process used in industry and commerce or into a new approach to a social service*." This description brings out the point that technological innovation involves more than R&D - it involves the workings of the market place. Equally, innovation can occur in any human activity, even though it is primarily thought of in the context of industrial production.

We have included in Part 2 of our report a first attempt to identify the outlines of China's national innovation system. In our approach we place emphasis on first identifying the ***functions*** of a national system of innovation and secondly on identifying the ***stakeholders*** whose interests are afffected by the system. Any analysis of the functions of a national system of innovation needs to take account of

- Policy and Resource Allocation Functions:
- Regulatory Functions:
- Financing Functions
- Performance Functions:
- HRD and Capacity-building Functions:
- Infrastructure Functions

The groups of 'stakeholders' include

- Policy-making institutions
- The Principal S&T Institutions:
- New Organizational Forms created by the Reform Process:
- Organizations of the Scientific Community
- Relevant Financial Institutions
- Regulatory Bodies

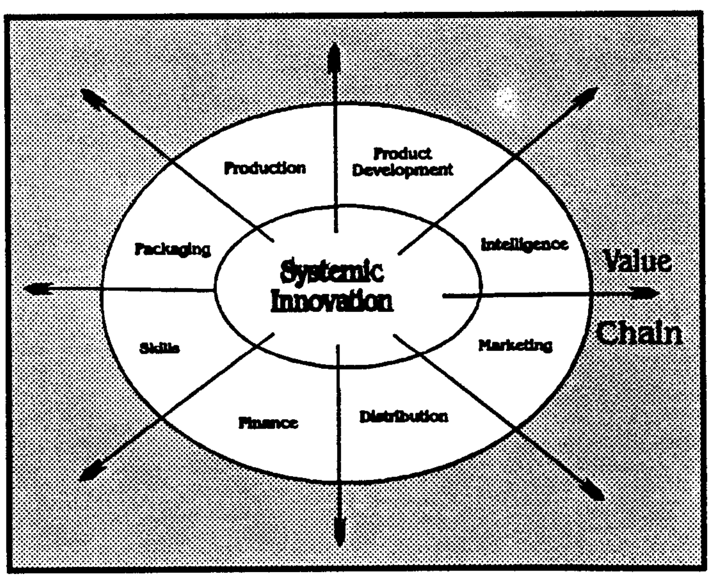
Models of Research, Development and Innovation

Many people with whom the Mission met appeared to base their ideas on a simplified linear model of research, development and innovation. This model, which is usually referred to as the 'technology push" model and which has been largely abandoned in the industrialized world, would suggest that these processes are simply linked in the some variation of a scheme such as

basic research → applied research → technological development → innovation

The practical consequences of belief in this model are that institutions and programs tend to be situated at discrete points along this spectrum, specializing in one or other activity, and tend to be organized along scientific disciplinary lines (eg institutes of basic research in some aspect of physics).

Other models of the innovative process have been developed over time, seeking to incorporate the ideas of 'market pull' and of the need for interaction amongst a whole range of technical activities which are seen to contribute to innovation in a modern enterprise. The latest attempt to understand the innovative process - and hence to be able to prescribe ways of enhancing the innovative performance of enterprises or institutions - is the so-called 'system integration and networking model' An Australian review of innovation studies[11] underlines the point that current models of the innovative process



emphasise that innovation should be viewed as a team effort, with formal and informal networking as the crucial factor in transferring knowledge amongst participants. These models recognise that there can be both long-term and short-term outcomes of the innovation process and that different technologies induce different patterns of innovation and diffusion, including new interdisciplinary groupings.

The [so-called] fifth-generation innovation process (See Figure) identifies the need for firms to be systematically innovative in all of their activities. This includes their linkages with customers, suppliers, information sources, research providers and all the various parts of their networks. In particular, the growing interdependence of national economies - so-called globalization - means that these linkages must be global as well as national.

11 See Tegart, G "*The Co-operative Research Centres Program*" Nexus Report No 6/95, University of Canberra, Sept 1995

The reference in the Figure to the "Value Chain" is to the technological trajectory followed by innovative enterprises as they continually seek to introduce greater added value to the products or services which they offer on the market.

In the industrialised countries, much attention is paid to fostering the creative interactions among people doing research, design and production and has lead to the creation of new groupings of scientists and engineers - in networks and consortia - and to significant investments in research at the frontiers of science in areas which are considered to be likely sources of future technological development of economic or social importance. (so-called 'strategic research'). China should carefully examine the utility of this experience as it moves to further institutional reform in its S&T system.

The Role of Key Laboratories, Engineering Research Centres and National Research Centres.

The S&T Reform process has given rise to three 'institutional innovations' which have been superimposed on the existing extensive and complex organizational structure of Chinese S&T. These innovations were

- the designation of a series of ***national key laboratories***; this program began in 1984 and today 99 such laboratories have been identified, 50 of them being located in institutes of the CAS. Selection of laboratories to be so designated involved a peer-review process organized by the National Natural Research Foundation, with the final decisions having been made by SSTC jointly with the State Education Commission.;

- the establishment of an extensive series of ***engineering research centres***[12], (ERCs) proposed as vehicles for improving the transfer of domestic and foreign technology to enterprises. To date, SSTC has established 25 out of a planned 56 ERCs, the State Education Commission has financed 14, and the World Bank has given approval for the financing of 46 . It is expected that there will be more than 200 such Centres by the year 2000

- the establishment, during the Ninth Five Year Plan (1996-2000) of a series of at least 10 ***national research centres*** which appear to come in three types:

  * *the geographically-distributed network,* in which institutes and laboratories in different locations form linkages among their activities;

  * *the consortium in a common location,* in which different organizations (State Key

12 According to World Bank Report #12814-CHA, cited earlier, "The ERCs would be market-oriented independent limited companies under Chinese Law, with the objective of adapting, developing and diffusing technologies, in particular those that have positive environmental impacts. The ERCs will produce, under contract, equipment and systems designs, prototypes and customised products and services that adapt foreign and domestic technology to local inputs, scales of production, and other market conditions.....

Laboratories, university institutes, CAS institutes) join together in a common effort to define a joint research program based on the strengths of the different participants; and

* *the new centre in new facilities,* a costlier version which involves investment in new physical plant.

The original motivation behind the designation of national key laboratories appears to have been a desire to consolidate, and assure continued governmental funding for, a series of the most productive labs engaged primarily, but not exclusively, in basic research, thus ensuring that national competence was maintained at the frontiers of research in what were perceived to be important disciplines. The Mission did not have the opportunity to explore the systems of governance of these key laboratories, so we are not able to comment on the provisions which have (or have not) been made to involve external peers in processes to assist the Laboratory Director to maintain standards of scientific quality.

The various engineering research centres appear to have been selected on a competitive process, with individual institutions of many types making proposals to the sponsoring commissions. This approach has the merit of basing the Centres on established technological capacity but gives rise to questions about the extent of national coverage which will be achieved, even with more than ~~a~~ 2 hundred such centres eventually being set up. The Mission could find no evidence of any concern to understand the geographic dispersion of the Centres; are they located in places which give them easy access to the enterprises most likely to need their services? What kind of outreach capacity will the centres have so as to take their services to potential clients? What kind of networking will be promoted to allow the set of centres to respond quickly to client needs?

For the medium term, a larger question arises. Will these Centres, at some future date, be elements of a national system of technical support to Chinese enterprises? If such a system were to emerge, how would it be organised? How would its activities be financed? What range of services would it offer? From experience in both industrialised and developing countries, the five most common needs of small and medium scale enterprises (of which there must be many in China) are for

- ☐ Access to finance (and China has already a variety of schemes at the national, provincial and municipal level);
- ☐ Access to management training;
- ☐ Access to market information and to markets;
- ☐ Access to skills-upgrading for employees affected by technological change in the workplace; and
- ☐ Access to best-practice technology where best-practice is defined in terms of the acquiring enterprise's capacity to absorb the technology in question.

There is a rich international experience in providing technological assistance to companies, both in the industrialized and in the rapidly-developing countries, and SSTC might consdier investigating the applicability to China of some of the experiences of programs such as

- the Manufacturing Extension Partnership (MEP) operated by National Institute of Standards and Technology (NIST) in the USA;
- the IRAP Program operated by the National Research Council of Canada;
- the Technology Adoption Program of the Singapore Institute of Standards and Industrial Research; and
- the Technology Commercialization activities of the Fundacion Chile

In each of the four examples cited, great emphasis is placed, by the program management, on the need to hire staff with many years of industrial experience. We surmise that the Chinese ERCs will begin by being staffed by former researchers from within the sponsoring institutions, and so would caution ERC management to watch carefully to identify those staff who have a genuine understanding of the operating environment within enterprises. The enterprises whom this staff will advise all have to face the daily challenge of the market; the advisors need to understand the nature of that challenge.

The introduction of the concept of the national research centres, as the Mission understands them, offers opportunities to introduce the most progressive of Chinese enterprises into new forms of joint activity now common in the industrialised countries. Much 'strategic research' (ie research at the frontiers of knowledge in fields of science and technology believed to be important to future economic performance) is now carried out by networks or consortia of R&D institutions and in most countries, these consortia include research institutions from government, the universities and enterprises. If China was to take steps to involve enterprises in the new 'National Research Centres' - both in their governance structures and in their research teams - it would be creating powerful institutional means to draw on the traditional strengths of the national key laboratories and on the emerging skills of the engineering research centres, in creative ways to focus enterprises' interests in their own longer-term development. This, the Mission believes, is an opportunity worth exploring.

Good examples of new forms of collaboration are to be found in

- the Australian 'Co-operative Research Centres Program', funded by the Australian Commonwealth Department of Industry, Science and Technology ;
- the Canadian 'Networks of Centres of Excellence Program', funded by the Natural Sciences and Engineering Research Council of Canada; and
- industrial R&D consortia operated under the US Federal "National Cooperative Research Act" of 1984

Human Resource Issues

It would be impossible for an international mission to ignore the enormous problem bequeathed to Chinese science by the Cultural Revolution. For almost ten years between 1966 and 1976 not only was scientific research, especially agricultural research, in disarray, but also scientific education in schools and universities was severely disrupted. There must be few scientists over the age of 40 whose training and research were unaffected.

We were impressed with the extent to which this legacy is recognized in China today and by the steps which are being taken to remedy and rectify it. The measures mainly call for retirement of older scientists, moving others away from research to routine activities, some retraining of middle-aged scientists, and special inducements, rewards and early promotions for younger and middle-aged scientists of quality.

There also seems to be a long term view on the brain drain. When the open door policy was introduced, many Chinese scientists were sent overseas for further education and training. Many decided to remain overseas, especially following the events of June 1989. Despite this loss, China decided to maintain the flow of scientists going overseas. Now, that policy seems to be paying off. The Mission heard of many younger scientists who have returned to senior positions. Others are encouraged to return to give lectures or to develop collaborative research programmes involving Chinese institutions and their own foreign institutions.

No other country has been faced with such a legacy, which at the same time provides huge opportunities and responsibilities for the younger generation. How well the aftermath of that legacy is managed will be one determining factor in how well China can implement its ambitious policies.

Some Costs and Benefits of the S&T Reforms in Institutions

From the interviews with individuals working in Research Institutions and Universities, the Mission drew up the following, very tentative, balance sheet of costs and benefits of the S&T Reforms of the last decade.

Some Benefits of the reforms for Research Institutions

- They provided mechanisms to permit the best researchers to concentrate on research and to allow others to be usefully employed in "spin off enterprises"
- They increased mobility of researchers, which allows top institutes to attract top scientists.
- They required Institutions to find new ways of linking their work to societal needs.
- They provided peer-review mechanisms for concentrating resources in the best groups
- They put heavy emphasis on encouraging talented young and middle-aged scientists.
- They provide more opportunities for returning Chinese scientists.

Some Costs of the reforms

- They led to commercially-unskilled scientists trying to become entrepreneurs and enterprise managers with, as a consequence, many enterprise failures.
- They led to a move of bright young scientists away from basic research. because financial rewards are potentially higher for applied research, which has created more opportunities for employment with new enterprises,
- They led to rewards within institutions being, preferentially, for those who can "sell their services and technology." This increases competition between departments and leads to "short term" research and major difficulties in promoting interdepartmental and interdisciplinary research.
- They led to the Directors of many Institutes having little opportunity to "direct" as individual researchers exploit the market to find funds to support their own research.

Some key unresolved issues

- There are still too many governmental research institutes
- Too many institutes are overstaffed
- Some important new tendencies in the global organization of S&T have still not been fully grasped or institutionalised in China.

Some Final Observations

We have begun this report with a set of comments covering the main impressions which we gained during out visit to China in November. As we finish it, we wish to add a few further observations, more oriented to our impressions of useful future directions for China to consider pursuing, in the light of experience in other parts of the world.

We share the view that science and technology are the driving forces behind contemporary economic development and that they have great potential to contribute equally to social development, provided that their development and application are carefully managed.

Given China's enormous population and the limitations which it faces in its available arable land, we agree that high priority has to be given to agricultural development through R&D; the two major concerns in this area to which China should pay attention are the need to have policy statements backed up by appropriate budgetary expenditures, both by governments and by enterprises, and the need to turn the large array of existing agriculture-related S&T institutions into an efficient and effective *system*.

To tackle the problems of accelerating industrial growth through technological innovation, China's national system of innovation needs to evolve into an increasingly interactive system, ending the tradition of institutional isolation of the past. There is also a need to pay greater attention to the effective assimilation and mastery of imported technology as an essential precursor to having enterprises become a continuing source of innovative activity.

The CPC Central Committee and State Council Decision on Accelerating Scientific and Technological Progress (6 May 1995)

This decision is based on eleven major points, some of which are supplemented by a series of principles. The major points are the following:

I **Implementing the idea that Science and Technology are primary productive forces in all fields.**

II **Energetically push forward scientific and technological progress in agriculture and rural areas;**

III **Improve the quality and efficiency of industrial growth through advances in science and technology;**

IV **Develop high-technology and its industries;**

V **Promote scientific and technological progress in social development;**

VI **Firmly tighten basic research;**

VII **Continue to restructure science and technology management and establish a new system of science and technology management, compatible with the socialist market economic system and the law of scientific and technological development.**

VIII **Train a contingent of highly qualified scientific and technical workers and enhance the whole nation's scientific and technological level;**

IX **Increase science and technology inputs through various channels and at different levels:**

X **Further opening up China to the outside world and extensively launching international scientific and technological cooperation and exchanges;**

XI **Effectively strengthening Party and Government leadership over scientific and technological work;**

Ref. 7

Becoming an increasingly innovative society requires that government create a policy environment which is designed to foster creativity and investment. This in turn requires that all of the principal policy-making bodies of government work together and consciously work at integrating the many elements of government policy into the desired whole.

The Mission is in favour of the policy of continuing to support research at the forefront of scientific knowledge and we believe that China has the capacity to undertake not only ventures into 'big science' but also to develop a strong tradition of strategic research which is closely articulated with its shorter term programs of technological development. To do this, some institutional realignment will be needed, and international experience in designing research consortia should be helpful.

We are strongly in favour of the openness which has been developing in China's S&T system over the last decade, and see the exposure of young Chinese scientists to foreign ways of doing and managing science as being crucial to China's own efforts.

Part 2 - The Detailed Observations of the Mission

Chapter 1: Some General Observations from the Mission About the Reform Process

The task facing the Mission was a daunting one: in three weeks it was to attempt to assess the results of S&T reforms which had been implemented over more than a decade, in a country with more than 4 million scientists and engineers and 20 000 S&T institutions. Furthermore, many of the fundamental institutions of China's economic and social system were undergoing change.

It soon became evident to the Mission that the utility of its views of what was happening to S&T in China would be profoundly conditioned by its understanding (or lack of understanding) of what was happening in the overall process of change in the country. We therefore feel it necessary to summarize the state of our knowledge of what is happening in the Reform process in general, how the roles of some key institutions - particularly the operational ministries of government - are changing and what added complexity springs from the current state of national-provincial -municipal relations in the fields of S&T. We devote this Chapter to setting out our views on these important background issues.

The Evolution of the Reform Process

China's S&T system emerged from the Mao Tse Tung period with many problems. By the end of the Cultural Revolution ~~period~~, research institutes, universities, enterprises, and all other "work units" in urban society had become cellularized enclaves of work and social services that were resistant to any forms of coordination and cooperation. Research agendas tended to be stagnant, there were no possibilities for professional personnel to move to better opportunities or to positions better suited to their knowledge and skills (they were regarded as "unit property"), and productivity gains in the economy were falling.

Meanwhile, outside of China, the world's science and technology had developed rapidly during the years when the Cultural Revolution's radical politics occupied China's national attention. The market economies of the capitalist world, including China's Asian neighbors, were increasingly basing their further growth and development on productivity gains brought about by technological and managerial innovations ("intensive growth"), while China and others with centrally planned economies continued to rely on the mobilization of new sources of labor and capital inputs to expand economic activity ("extensive growth"). It was appropriate, therefore, that as the post-Mao period began, it did so with the major National Conference on Science and Technology of 1978.

The Conference marked the beginning of the S&T reform process which still continues today. While the Conference attempted to set a broad and ambitious research agenda for basic science and high technology (an agenda which was abandoned and/or postponed within a year of its announcement), the Conference's greatest significance was ideological. In an attempt to reverse the low status of science - and of scientists and engineers - which had resulted from onslaughts against technical intellectuals during the Cultural Revolution, Deng Xiaoping's speech at the Conference celebrated the roles of scientists and engineers in society by making it clear that S&T were principal "productive forces" (and not part of the "superstructure"). Scientists and engineers should therefore be regarded as part of the working class, and not somehow politically suspect as they had been since the Anti-Rightest Movement of the late 1950's. The "Four Modernizations" policy was reaffirmed, and the modernization of science and technology was seen as the basis for the modernization of agriculture, industry, and national defense. From this basic ideological change came a gradual improvement in the political standing of technical intellectuals, including the gradual replacement of political cadres in leadership roles in research institutes and institutions of higher education (IHEs) by qualified scientists and engineers.

By the early 1980's, the ambitious research themes of the 1978 Conference had been replaced by a more practical orientation of having science and technology serve economic development and having economic development be based on science and technology. This orientation, of course, also continues until today. However, the pursuit of this objective in the early 1980s required that the chronic separation of R&D from economic production be overcome, that the operational mechanisms and management principles of both R&D and the economy be changed, and that scientists and engineers have the professional mobility needed to insure that their talent be used appropriately. For both research institutions and industrial enterprises, which had long been comfortable in receiving their annual appropriations without concerning themselves with national innovation needs, the implementation of the new orientation would require major reforms - reforms in the economy as a whole, in enterprise management, and in the S&T system.

Against a background of aggressive acquisitions of foreign technology to upgrade quickly the technological levels of Chinese industry, the early rural reforms, and the beginnings of reforms in the urban economy, various reforms in the S&T system began in the early 1980s on an experimental basis. Perhaps the most important of these was a series of measures intended to change the ways research was funded. The old system of guaranteed annual appropriations from the state served neither basic research nor applied research and development well, in that it provided for no effective mechanisms of accountability - either to peers for quality basic research, nor to the economy for applied work which required economic justification.

In the face of increasing exposure to foreign governmental and corporate models for organizing and managing S&T, China began to encourage new "multi-channel" approaches to funding. These included a trial research "foundation" run by the Chinese Academy of Sciences in which investigator initiated proposals for support - from both CAS and non-CAS researchers - would be subject to peer review before funding. This CAS program was then superseded by the National Natural Science Foundation (NNSF) when it was established in 1986. The Mission was impressed throughout its visit by the high regard with which NNSF and its programs are held, and by the fact that many in the Chinese technical community comment on the positive effects this new approach to research management have had. Indeed, throughout the 1980's, as new national research programs (such as "863") were launched, the principle of peer review was embraced by policy makers, administrators and researchers as a critical element in sound research management.

In addition to the new "foundation" approach to funding, other approaches were also introduced. In particular, efforts were made to encourage the flow of funds through "horizontal" channels, especially between research institutes and enterprises and between research institutes and local governments. This involved the encouragement of contract research or the open sale by institutes of their research results. It soon became clear, however, that in order for these measures to work, a series of other important changes in policies and attitudes would be required. Research institutes and institutions of higher education had to be induced to want to take the trouble to enter into contracts and to market their results. The means chosen for this was the gradual reduction of guaranteed annual state appropriations to institutes deemed to be doing work of an applied nature. But once these elements of marketization were introduced, it also became clear that if technical knowledge was to be considered more of a commodity, it would be necessary to find a means to place a value on that knowledge, and to clarify and protect the ownership rights of this commodity. The establishment of China's patent system in 1985 represented a step towards meeting the latter objective.

The March, 1985 Resolution of the Central Committee of the Communist Party on the Structural Reform in Science and Technology represented an effort to sum up and formalize many of the reform experiments of the early 1980s, and to push the S&T system reform to higher levels. Key concepts in reform thinking throughout the 1980's which were incorporated within the Resolution were that market mechanisms should be substituted for administrative ones in the S&T system, where possible and appropriate, and that S&T reforms should be harmonized with the broader ongoing economic and enterprise management reforms.

The Resolution and subsequent laws and policies unleashed a whole range of reform initiatives which have had the effects:

- of changing the ways S&T are thought of in society (involving, in particular, the idea that technology can be treated as a commodity which can be bought and sold in the market),
- of changing the ways S&T activities are funded, and
- of stimulating a range of institutional innovations to exploit market opportunities for technologies.

The latter have included institutional innovations which have expanded the range of ownership arrangements of institutes and technology oriented enterprises from that of the single government owned type to collective and private forms.

Of particular interest were the efforts made to further stimulate the relationships between research and production by

- clarifying the state's determination to reduce or eliminate traditional "vertical" sources of funding,
- by further encouraging and formalizing technology markets and,
- by encouraging the merging of research institutes and enterprises.

Partly as a response to these initiatives, by the mid-1980's, China was seeing efforts by research institutes and institutions of higher education, and by individuals, to commercialize technical knowledge through the establishment of new companies. These were established for the merchandising of technology intensive equipment, for technical services, and in some cases, for the introduction of new products. In addition to serving the reform objective of commercializing research, these "new technology enterprises" also provided a means for pursuing other reform objectives including finding alternative sources of funds for research units, increasing the mobility of scientists and engineers, and helping research units to reduce the numbers of redundant staff they had accumulated.

The successes of these reforms during the late 1980s and early 1990s have been mixed. With new sources of funds from innovative state projects and programs, and with "horizontal" flows of funds beginning, capable and aggressive institutions and/or individuals were able to actually increase their overall revenues in spite of the loss of some or all of their core state funding. Others, however, saw their absolute amounts shrink, and either because of their fields of study, lack of entrepreneurship, or lack of quality, began to experience very hard times.

The efforts to establish strong horizontal links between research units and enterprises also had mixed results. Research contracting and technology markets have developed, but both institutes and enterprises have at various times and in various ways been dissatisfied with these mechanisms. For instance, enterprises felt that institutes were not providing packages of technology which could be directly employed in production, and institutes felt that state owned enterprises still had not developed an appreciation for the value of technological change. Differing approaches to placing a value on technical knowledge, and of distinguishing between codified and tacit knowledge also has created difficulties. Interestingly, with the growth and economic success of collectively owned township and village enterprises (TVEs), the research institutes gradually began to find a greater demand for their knowledge and skills among these new types of enterprises than they did with the state-owned enterprises. In addition to entering into contractual arrangements with institutes for the transfer of codified knowledge, TVEs have also hired scientists and engineers away from research centers, a practice which has led to intellectual property rights being disputed in the courts. Efforts to merge institutes and enterprises have also run into difficulties because of problems of technological asset valuation, because of differing organizational cultures, and because such mergers could not be accomplished without one side having to shoulder the social services burdens which the new partner would inescapably carry with it.

Meanwhile, as reforms in the operational mechanisms have proceeded - with both accomplishments and problems - new national programs have been introduced which both focus on national economic and research objectives and which seek to employ and promote the new operational mechanisms. Among others, these include the Key Technologies Program (1984), the Spark Program (1986), the National High Technology Program, or "863" (1986), the Torch Program (1988), and the Climbing Program (1991). the distribution of these programs, and their emphasis on commercialization of technology, is shown in the following table. (The simple classification used follows the 'linear model' of R&D which the mission encountered in its discussions)

Basic Research	Applied Research	Extension or Commercialization
The National Key Laboratory Program	The National Program for Tackling Key Technology Problems	The National Program for Key Industrial Experimental Projects
National Funds for Natural Sciences		The Industrial Technology Extension Program
		The Spark Program
		The National S&T Achievements Spreading Program
The "Climbing Program"	The National Development Program for Hi-Tech (the '863 program')	The Torch Program
		The Trial Production and Appraisal Program

By the early 1990s, China's S&T system - and the broader society and economy - had changed dramatically from what it had been a decade before. S&T policy and reforms were important parts of this change. By promoting the importance of S&T knowledge for a modern society, and the importance of those with such knowledge for the functioning of such a society and the organizations which make it up, the S&T system reform process continued to call attention to the need for more economic and social reforms. In 1992, a new and ambitious vision for China's S&T future was introduced in the National Medium and Long Term Science and Technology Development Program. The successful implementation of this plan presumes continuing institutional reform in the S&T system itself, but also in the economy, in law, and in social security arrangements. Followed as it was by the critically important *Decision on Issues Concerning the Establishment of a Socialist Market Economy*, made by the 3rd Plenary Session of the 14th Party Conference in November, 1993, the stage was set for important new initiatives in S&T and the economy as China began to prepare for the 9th Five Year Plan and the countdown to the year 2000.

The 1995 National S&T Conference and CCP Central Committee and State Council Decision on Accelerating Scientific Progress thus can be seen as occurring at the convergence of a number of different factors:

- the experiences of more than a decade of successes and failures with S&T reforms and with the other S&T programs alluded to above;
- important streams of new reform thinking based on the idea of a socialist market economy, thinking which in turn is driven by the reality that China's rapid economic growth has been driven more by economic activities outside of the state sector than by those within it;

- the overall improvement of China's technological level over the course of the reform period as a result of the very large expenditures on "technological renovation" (***jishu gaizao***) over the past 15 years. While some of this technology has come from China, a great deal of it has come from massive procurements of foreign technology. The introduction of advanced foreign technology continues with the surge of foreign investment - often in high technology fields - which has occurred in the early 1990s;
- the impending competitive challenges China will face with its eventual admission to the World Trade Organization, and the fact that its domestic industries will face even more competition than they have thus far under the Open Door policy of the past 15 years. To meet the challenges which WTO membership will bring, China is seeking to reorganize its industrial structure in order to insure that it has firms ("pillar industries," "national champions") which have the size, technology, and managerial skill needed to compete in the global economy.

The convergence of these factors poses enormous challenges and opportunities for China's S&T policy and reforms. As a number of individuals mentioned to the Mission, the reforms since the 1985 Resolution have had greater influence on the operating mechanisms of research institutions than on the broader problems of coordinating S&T activities for the society as a whole. The very nature of the convergence of the four factors identified above insures that a number of contradictory forces must be managed and this fact, in turn, again calls attention to broader issues of the coordination and integration of what might be called the national system of innovation.

Among the possible contradictions, the following stand out:

- State support for the creation of pillar industries must be reconciled with policies for an economically liberalized domestic market and with a liberalized foreign trade and investment regime. Domestic R&D polices will have to be synchronized with the technology flows found in the global economy.
- R&D, and overall technology, management in pillar industries must come to resemble the technology strategies of the modern multi-national corporation, not those of ministerially guided state enterprises of the past. S&T policy, therefore, must be developed in the context of changing industrial organization, the contours of which have yet to be fully understood.
- Since the S&T interests of the dynamic non-state sector will not always converge with those of state owned and directed pillar industries, ways must be found to reconcile the interests of both in national S&T policy.

The potential for government policies to be internally inconsistent and for government agencies to work at cross purposes in the face of such challenges is quite high. China, of course, is not alone in this; many other nations have the same problems as they attempt to adjust to global forces. What sets China apart is that it is in throes of attempting to adjust to and exploit the globalization of industry and technology while at the same time continuing the still incomplete process of reforming its old S&T system.

The Role of Ministries in S&T Decision-making

Among the many interesting issues for the future Reform of S&T in China is that of the definition of the changing role of the national production ministries which, in the past, had important influence over the direction of S&T activities.

Understanding the changing role of ministries in Chinese S&T and economic reforms can be thought of in two ways: one can think of either

- their roles *vis a vis* the central government and its coordinating commissions (SSTC, State Economic and Trade Commission, State Planning Commission, State Education Commission), or
- their roles *vis a vis* local government.

In the pre-reform economic system, industrial ministries played a large role in decision making, including S&T decision making. Plans for production and for research were developed within the ministerial system, and most of the assets for research and production within a given industry were controlled by the ministry. Within the state sector today, this continues to be true. Ministries run institutions of higher education, for instance, somewhat independently of the State Education Commission, though these remain under the policy guidance of the State Education Commission. Similarly, SSTC can set policy guidance for the ministerial S&T system - on reform policy, for instance - but since policy is separate from budgeting, large areas of discretion remain with the ministries. Because of the roles of the State Planning Commission in national budgeting, and of the State Economic and Trade Commission in dispensing technical renovation funds and in State-owned enterprise management reform, the power of these commissions over ministries is even greater.

When viewed in relation to local government, a somewhat different picture emerges. In contrast to the old Soviet Union, centralization within a ministerial system was considerably weaker in China as a result of conscious decentralization of decision-making going back to the late 1950s. As a result, local governments - with a local industrial bureau matching the national ministry - have had a significant role in economic decision making. Thus, in considering the role of ministries in the past, it was helpful to think in terms of two systems of organization leading to a complex pattern of "dual leadership." While there are changes in course, as noted below, these systems continue today.

The first system is a vertical one, led by a central ministry in Beijing. For large State-owned enterprises and many large and nationally important research institutes, the central ministry provides primary leadership. Cross-cutting the vertical system, however, is a horizontal one led by local government. Within local government, there are industrial bureaus which are accountable to both local political leadership bodies and to the central ministry. Many State-owned enterprises and research institutes are under the leadership of these bureaus, while also following broad industry-wide directives set by the ministry.

Broader economic and managerial reforms now in course have created much confusion about the role of the ministries. Some ministries (eg., Electronics, Shipbuilding, etc.) have already converted most of their assets into large corporations, and this may be the direction others will go. However, it remains unclear what the residual role of government is to be. This was evident during our visits in Liaoning. With the growth of managerial autonomy and the processes of "corporatization" and "enterprisization" of State-owned enterprises and institutes, the question of the prerogatives of industrial bureaus has become an issue. In Liaoning, for instance, the local industrial bureaus still appoint the directors of the successfully reformed institutes we saw, but do not interfere in most other aspects of operations. Since they no longer provide any budgetary support, the newly "enterprised" institutes expect to enjoy the autonomy of a company operating in a market environment. However, the local bureaus are still exacting a percentage of the institutes' revenues as in the past. A clearer definition of the role of government in this case appeared to be a pressing matter effecting the future development of the institutes involved.

Similarly, with the corporatization of large State-owned enterprises into limited liability share issuing entities, the question of ministerial control is again an issue. At Anshan, for instance, we were told that the Anshan Iron and Steel works (Angang), now being reformed into a company, was already competing in the market against other steel works (eg., Baoshan) which are also are under the Ministry of the Metallurgical Industry. Angang's Iron and Steel Research Institute still has a close relationship to the S&T system of the Ministry, implying that - as in the past - its work is intended to serve the whole industry over which the Ministry has cognizance. Clearly, at some point, contradictions and conflicts of interest are likely to arise if the research results from Angang's laboratories are transferred through ministerial mechanisms to a competitor in the market, such as Baoshan. To further confuse the situation at Angang, it is in the process of negotiating foreign participation in the financing ***and management*** of one of its subsidairy enterprises, creating a new level of ambiguity of ownership within the structure of the overall complex.

Given complexities of this sort, the pace of reform in the industrial economy - especially reforms dealing with share-holding and property rights - seems to be becoming a limiting factor in the reform of the industrial S&T system and in the implementation of an effective national industrial S&T strategy of the sort which recent policy documents have called for.

Central-Local Relations

The Mission also came to believe that the changing nature of the relationships between the central and local levels of government in S&T will develop as an issue in future.

Central-local relations in China have always been very complex, and they appear to be becoming more so. As a result of decentralization decisions which go back to the 1950s, local governments (provinces, cities) have substantial powers. Nominally, China is a unitary state (not a federation) in which powers of local government are delegated from the center. The organization of local government, thus in many ways, resembles that of the center, with local commissions and industry bureaus having roles analogous to central commissions and ministries. These local entities, however, are not simply branches of the central entities. They tend, instead, to also be agencies of local government. Many of China's State-owned enterprises and much of the S&T system, are under the local governments. Large and nationally important enterprises and research institutes, however, are centrally controlled. Nevertheless, these units also are subject to local influence and coordination.

In the reform era, the wealth and power of many local governments relative to the center has increased, although the wealth and power among local governments has become considerably more unequal. With the funding changes that have reduced the "vertical income" of national institutes and institutions of higher education and encouraged the development of "horizontal" revenue flows, the possibility of local governments increasing their influence with national S&T units has increased.

The Mission had opportunities to observe center-local S&T relations in 4 different settings (excluding Beijing), and found that there were considerable variations. Indeed, we identified at least three different models at work.

The Guangdong model is at one extreme. Guangdong is a leader in reform and is extensively integrated into the world economy. As a very wealthy province, but one which traditionally had a much more limited concentration of S&T assets (numbers of scientists and engineers, institutes, and institutions of higher education) than other places visited by the Mission, the role played by the provincial government, in the direction of the S&T work done in the province, is very strong. Reportedly, 70% of the government funded R&D in the province, including that done by nominally central institutes, is funded locally. The Branch Academy of the Chinese Academy of Sciences has long been closely linked with the Guangdong Academy of Sciences in ways which are not seen elsewhere (they share the same building and have overlapping staff, for instance).

A second model would be based on the Liaoning and Shanxi experiences. Both places have been rich in S&T assets, especially those controlled by the center. In addition to S&T assets, they have been centers of strategic and domestic high technology industries. However, both have been slow in reform and are less well integrated into the international economy. The provincial governments seem to have less money to induce cooperation from central units. The Shenyang branch of CAS, for instance, seemed much more oriented towards the central CAS than to provincial concerns.

A third model is that found in Shanghai. Like Liaoning and Shanxi, Shanghai is rich in S&T assets, including those which are under central control and those which are under the Shanghai government. Although Shanghai was slow in reform at first, it is now moving rapidly. Shanghai and the lower Yangtze Valley are becoming favored destinations for foreign investors in technology intensive industries. Shanghai has long had a problematic relationship with the center over centrally controlled State-owned enterprises and institutes whose location in Shanghai put additional financial burdens on the city without providing appropriate returns. However, as Shanghai's wealth continues to grow and as it grows into its role as one of the most important - if not ***the*** most important - point of connection with the global high technology economy, it seems inevitabl that central institutes will
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become integrated into local and regional initiatives. An interesting case of this is the creation of the new Shanghai Academy of Sciences. While this Academy, at the moment, consists only of institutes which belong to the city, it may provide an organizational structure into which central institutes might fit.

Chapter 2: Innovation and a 'national system of innovation';

OECD provides a useful and brief definition of "innovation" as being "... the transformation of an idea into a new or improved product introduced on the market or a new or improved operational process used in industry and commerce or into a new approach to a social service." This description brings out the point that technological innovation involves more than R&D - it involves the workings of the market place. Equally, innovation can occur in any human activity, even though it is primarily thought of in the context of industrial production.

The overriding objective of China's S&T Policy since the beginning of the reform policy has been that of "*Implementing the idea that Science and Technology are primary productive forces in all fields*"[1] In the terms used in the industrialised countries, this policy measure is one which calls for the promotion of technological innovation throughout a society and economy. In a country with such a policy orientation, it is now considered to be useful to seek to identify the elements of a 'national system of innovation' and then to use this concept as a basis for policy formulation. The present Mission has found this a useful approach to help in understanding the complexity of the Chinese S&T system and to identify the roles being played by the key stakeholders whom we define and identify below. It also permits the identification of any gaps which might exist within the system.

The Concept of a National System of Innovation and its use as a Policy Framework

There have been many attempts in the industrialised countries to put forward a concise definition of a 'national system of innovation; one such definition, provided by OECD calls such a system *'a network of institutions in the public and private sectors whose activities and actions initiate, import, modify and diffuse new technologies'* An alternative, somewhat fuller definition is *'a system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology'*.

A national system of innovation can be thought of as a ***set of functioning institutions, organizations and policies*** which ***interact*** constructively in the pursuit of a ***common set of social and economic goals and objectives***, and which ***use the introduction of innovations*** as the key promoter of change.

The four key interests, then, of any country can be thought of as being:

1 to ensure that it has in place a set of institutions, organizations and policies which give effect to the various functions of a national system of innovation;

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[1] See "The CPC Central Committee and State Council Decision on Accelerating Scientific and Technological Progress (6 May 1995)"

2 to ensure that there is a constructive set of interactions among those institutions, organizations and policies;

3 to ensure that there is in place an agreed upon set of goals and objectives which are consonant with an articulated vision of the future which is being sought; and

4 to ensure that there is in place a policy environment designed to promote innovation.

In what follows, we will first set out a listing of what we consider the essential functions of any national system of innovation and then we will proceed to look at the roles played by a variety of Chinese institutions in the implementation of these functions.

The Functions of a National System of Innovation

General Functions:	Specific Functions
Core Functions of Government	
Policy and Resource Allocation Functions:	☐ Monitoring, Review and formulation of policies and, in some countries, plans concerning national S&T activities; ☐ Linkage to other policy domains(eg those dealing with the economy, trade, education, health, environment, defence etc). ☐ Allocation of resources to S&T from overall budgets and first order allocation among activities; ☐ Creation of incentive schemes to stimulate innovation and other technical activities; ☐ Provision of a capacity to implement policies and to coordinate appropriate activities ☐ Provision of a capacity for forecasting and assessing the likely directions of technical change;
Regulatory Functions:	☐ Creation of a national system for metrology, standardisation, calibration ☐ Creation of a national system for the identification and protection of intellectual property. ☐ Creation of national systems for the protection of safety, health and the environment.
Implementation functions	
Financing Functions:	☐ Management of financing systems appropriate to the implementation of the other functions of the system ☐ Use of Government's purchasing power as a stimulus to innovation in the production of the goods and services which it requires

Performance Functions:	☐ Execution of scientific or technological programs, including research of all kinds and technological development ; ☐ The provision of scientific services ☐ Provision of mechanisms to link R&D outputs to practical use; ☐ Provision of linkages to regional and international S&T activities; ☐ Provision of mechanisms for evaluating , acquiring and diffusing best-practice technologies; ☐ Creation of innovative goods, processes and services embodying the results of S&T activities
Human Resource Development and Capacity-building Functions:	☐ Provision of programs and facilities for the education and training of S&T personnel; ☐ Creation of institutional capacity in S&T ☐ Provision of mechanisms to maintain the vitality of the national S&T community; ☐ Stimulation of public interest in and support of national initiatives in S&T
Infrastructure Functions	☐ Establishment, operation and maintenance of information services (including libraries, data bases, statistical services,a system of indicators, communications systems.) ☐ Establishment, operation and maintenance of technical services (eg metrology, standardisation, calibration); ☐ Establishment, operation and maintenance of a system of awarding, recording and protecting intellectual property ☐ Establishment, operation and maintenance of mechanisms to ensure the protection of safety, health and the environment. ☐ Establishment, operation and maintenance of major national facilities for research

This broad range of functions - both policy-related and implementation-related - are carried out by different stakeholders in any country's national system of innovation, with the particular combinations being unique to each country.

The "Stakeholders" in China's National System of Innovation.

In the industrialised countries, the term "stakeholder" is used in discussions of systems of many kinds, including discussions of national systems of innovation, to indicate the group of institutions and individuals who are either participants in the system in question or whose activities are significantly affected by the operation of that system. It is necessary to include in any analysis of a national system of innovation a clear listing of the relevant stakeholders and this we will now do. [Given that the Mission spent only three weeks in China, it is likely that we will have failed to identify some stakeholder groups, so the listing below may well be incomplete.]

Policy-making institutions

There are a series of important national commissions which have significant roles in China's NSI including:

- The State Science and Technology Commission, (SSTC) with its important roles in policy development and program implementation;

- The State Planning Commission (SPC), which is directly involved in the financing of a number of important S&T programs;

- The State Education Commission (SEdC), which has particular responsibilities for the activities of institutions of higher education;

- The State Economics and Trade Commission, (SETC) which has an important role in the technological renovation of enterprises;

- The State Commission for Restructuring the Economy, (SCRE) whose general economic reforms have in many ways interacted with reforms in the S&T sector;

- The many sectoral ministries which are responsible for individual sectors of the industrial economy and some of which are now undergoing transformation into what look like "holding companies" within the socialist market system.

- Some Policy Research Institutes, particularly the National Research Centre for S&T for Development (NRCSTD) and the Institute of Science Policy and Management (ISPM/CAS) of the Chinese Academy of Sciences

- Similar organisations to the above at the Provincial and Municipal levels

The Principal S&T Institutions:

* Research Institutes;
* State-owned Enterprises;
* Private, Joint-Venture, and Urban Collective Enterprises;
* Universities;
* Defence Research Institutes and Enterprises;
* Township and Village Enterprises;

These six kinds of organization constitute the heart of the Chinese National System of Innovation. All have been significantly affected by the reforms of the last decade.

Estimates of how many such organizations exist vary, but one attempt to summarise the numbers of those heavily engaged in R&D - and therefore having a significant potentail to promote innovation - is presented in the table on the following page.

New Organizational Forms created by the Reform Process:

The reform of R&D institutes in China can be seen as having had a series of objectives:

1 To reduce dramatically the dependence of many intitutes on annual budget appropriations from the state;

2 To introduce externally-reviewed or market-driven, competitive processes for funding research; and

3 To establish, within existing institutes, specialised groupings designed either to concentrate high-level teams on programs of 'strategic research' or to serve as improved vehicles for the commercialisation of technologies.

The principal organizational structures created to accomplish these objectives, and now important stakeholders in the national system of innovation are:

- The National Natural Science Foundation (NNSF)
- National Key Laboratories, selected on the advice of NNSF and funded by the SSTC, the SPC and, in some cases, the World Bank:
- The Research Laboratories of the State Education Commission;
- The Engineering Technology Research Centres supported by SSTC; and
- The Engineering Research Centres supported by the State Education Commission (and some about to be created with World Bank assistance)

Other Stakeholders

There are a growing number of foreign companies, foreign (development assistance) agencies and multilateral bodies active in China's national system of innovations, and their activities need to be taken into account.

An Estimate of the Numbers of R&D Institutions in China[2].

	1987	1988	1989	1990	1991
R&D Institutions under Government Departments	7 292	8 169	8 456	8 576	8 188
• of which Natural S&T Institutions	5 222	4 933	5 011	5 084	5 127
• of which Social Sciences & Humanities	346	342	343	332	336
• of which Information and Documentation		396	405	414	416
• of which other fields, including health	1 724	2 498	2 697	2 746	2 309
Institutions under the State Council	1 033	1 000	1 010	1 027	1 035
Institutions under Local Governments	4 189	3 933	4 001	4 057	4 092
Technological Development Institutions under Large and Medium Enterprises	5 021	5525	7 215	8 116	8 792
R&D Institutions of Institutions of Higher Learning	1 514	1 715	1 739	1 666	1 676
Collective and Private Technological Development Institutions	2 013	4 870	6 424	8 523	
• of which, Collective Institutions	1 536	3 407	4 359	6 047	
• of which, Private Institutions	422	1 239	1 740	2 243	
• of which, status unknown	55	224	325	133	
Total calculated by Yang Lincun	16 477	20 279	23 838	26 881	
Total	**21,062.**	**25,212**	**28,845**	**31,965**	

2 Adapted from Yang Lincun, Deputy Director, Policy Regulation Department, SSTC, writing in '*Present Situation and Future Development of Science and Technology in China*" Forum on Science and Technology in China, NRCSTD, Beijing, Vol1, No1, June 1994. There is an unexplained and large discrepancy in the totals as calculated by Yang.

In the listing of new organizational forms presented on page 5, the NNSF is a completely new and independent organization; the others are special components of existing institutes or universities.

In addition, SSTC has recently begun to plan a new set of "National Research Centres", to be established under the Ninth Five-Year Plan, which appear to come in at least three different organizational forms:

* *the geographically-distributed network,* in which institutes and laboratories in different locations form lingages among their activities;

* *the consortium in a common location,* in which different organizations (State Key Laboratories, university institutes, CAS institutes) join together in a common effort to define a joint research porogram based on the strengths of the different participants; and

* *the new centre in new facilities,* a costlier version which involves investment in new physical plant.

Organizations of the Scientific Community

- The Chinese Association for Science and Technology (CAST) and its constituent societies;

Relevant Financial Institutions:

- Banks which give loans for S&T and innovation-related activities;

- Venture Capital Organisations (at least one of which, in Guangzhou, is 'owned' by a Provincial S&T Commission)

Regulatory Bodies:

- Organisations responsible for the protection of intellectual property;

- Organizations for the protection of Health, Safety and the Environment;

- Organizations concerned with Standards, Calibration and Metrology

Of the Financial Institutions and Regulatory Bodies in China, the only one interviewed by the Mission - and that only briefly - was a Municipal Environmental Protection Agency (in Beijing)

The Roles of Stakeholders in the Performance of Functions of China's National System of Innovation

In the following tables, we explore the roles of different stakeholders in China's national system to the extent that we are able to do so based on our brief Mission to the country. We use a series of Tables (matrices) to map out the ways in which different functions of the national system perform and demonstrate that this mode of analysis can be performed at different levels of generality - eg at the level of the whole system, or for some subset of issues [eg financing issues], or for some subset of stakeholders [eg government institutions] .

Table 1 explores the roles of government stakeholders in the Policy and Regulatory Functions of the Chinese System while Tables 2 and 3 explore different stakeholders' relationships to the Financing Functions of the system. Table 4 explores the roles of a broader list of stakeholders in the Implementation Functions. Table 5 also uses the technique of displaying information in matrix form to display information on the participation of stakeholders in the programs administered by SSTC.

Table 2.1: The Roles of Government Stakeholders in the Policy and Regulatory Functions of the Chinese National System of Innovation

	Policy and Resource Allocation Funtions						Regulatory Functions		
Stakeholder	Policy Setting	Policy integration	Resource Allocation	Incentives for R&D	Policy and program coordination	Technology Foresight	Health, Safety and Environment	Intellectual Property	Metrology, Standardization, Calibration
State Council	✓	✓	✓		✓		✓	✓	✓
SSTC	✓	✓	✓	✓	✓	✓		✓	✓
SPC	✓	✓	✓	✓	✓	✓			✓
SEC	✓	✓	✓	✓					✓
SEdC	✓	✓	✓	✓					✓
Sectoral Ministries		✓							
CAS				✓		✓			
CAAS									
Provincial Commissions	✓	✓	✓	✓			✓		✓
Municipal Commissions	✓	✓	✓	✓			✓		✓
NRCSTD				✓		✓			
IPM/CAS									
CAST									

Table 2.2: Government Stakeholders and the Financing Functions of the Chinese National System of Innovation

	Financing Functions					
	Government Budgets	***Grants***	***Loans***	***Contracts***	***Tax Incentives***	***Government Purchasing***
State Council	Approves Budgets	Not involved	Not involved	Not involved	Has agreed to a variety of investment incentives	Would need to approve policy
SSTC	Advises on size and distribution	Provides grants		Provides contracts	Provides some incentives via Torch Program	
SPC	Provide Budgets	Provides capital grants to ERCs via a World Bank Loan		Provides Contracts		
SEC		Provides grants		Provides Contracts		
SEdC		Supports Engineering Research Centres		Provides some contracts		
Sectoral Ministries		support some programs		Provide some contracts		
Provincial Governments	Only some can provide budgets to their Institutes	Provide some grants	May guarantee loans to enterprises in high technology zones	Some provide contracts		
Municipal Governments						
Banks			Now major suppliers of loan financing			
NNSF		Major source of support, particularly to basic research		Provides contracts		

Table 2.3: Other Stakeholders and theFinancing Functions of the Chinese National System of Innovation

	Financing Functions					
Policy Instruments ▹	Government Budgets	Grants	Loans	Contracts	Tax Incentives	Self Financing Schemes
Stakeholders	Research and Development Institutions					
The Academies	Major recipients	Important recipients		Important recipients	May be eligible in some circumstances	Revenues from some spin-off companies
Government Institutes (State, Provincial Municipal)	Some get varying levels of government support, others are cut off	National Institutes may get some; others are less likely	Possible under some circumstances	Important source of revenue; some are entirely dependent on conrtracts	Not clear under what conditions they are eligible to recieve incentives	Some get into production activities in order to generate revenue for survival
Universities	Government grants cover most of staff salary bill	A Major ssource of R&D support		A second important source of R&D support		Revenues from some spin-off companies
	Enterprises					
State owned Enterprises	Many need recurring subsidies		Some may get subsidised loans	Some award contracts to for R&D	New facilities in designated zones are eligible	Profitable ones are self financing
TVEs	Not eligible		Interest rates may be subsidised			Should become self financing
Spin-offs and New High Technology Enterprises	Not eligible	In theory, can compete and a few are successful	Are eligible to have interest paid by government if located in a high tech zone		Are eligible for most favoured tax treatment in designated high technology zones	Should become self financing
Joint ventures	Not eligible		???		Are eligible for investment incentives	Have to be self financing

Table 2. 4: Stakeholders and the Implementation Functions of the Chinese National System of Innovation

	Performers			**HRD andCapacity Bulding**		**Infratructure**		
Stakeholder	***Research Development Innovation***	***Linkages and networks***	***Transfer and adpotion, including assimilation of foreign technology***	***Tertiary Education and training***	***Institutional capacity creation***	***Regulatory (Health, Safety, Environment)***	***S+T Information***	***Intellectual property***
SSTC	Has extensive programs	Gives preference, in National Programs, to proposals from more than one group	Supports Engineering Technology Research Centres and has other extensive programs	✓	✓	✓	✓	✓
SPC.	✓	✓	Supports Engineering Research Centres	✓	✓	✓	✓	
SEC				✓	✓			
SEdC	✓	✓	Supports Engineering Research Centres	✓	✓			
Sectoral Ministries	✓		✓	✓			✓	
NNSF	✓	✓		✓	✓		✓	
The Academies	✓	✓	✓	✓			✓	
Government Institutes (all levels of gov't)	✓	✓	✓	✓	✓	✓	✓	✓
Universities	**Much activity concentrated in a few leading institutions**	✓	✓	✓	✓		✓	
State owned Enterprises	Performance varies from sophisticated to nil	A Few involved	✓	✓	✓			
TVEs			Some are major recipients					
Spin-offs and New High Technology Enterprises	Many have activities in R&D	Some may participate	✓	✓				
Joint ventures	Some involved		Many involved in import of technology					

Table 2.5: The Role of SSTC and its Major Programs in Supporting the S&T Activities of the Principal Stakeholders in China's National Innovation System

Role of SSTC	Policy and Funding	Implemented with SPC and SEdC				Funding and Policy	Funding and Policy	Funding and Policy	Funding and Policy	Funding and policy		Policy
Program/ Stakeholder	**Key Technologies**	**Key Laboratories**	**Engineering Technology Research Centres**	**Key Industrial Projects**	**Industrial Technology Extension**	**863**	**Spark**	**Climbing Up**	**Torch**	**National S&T Achievements**	**Trial Production & appraisal**	**Agenda 21**
SSTC institutes	✓	✓	✓			✓	✓	✓	✓	✓		✓
CAS	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
CAAS	✓	✓				✓	✓	✓	✓	✓		✓
Sectoral Ministry Institutes	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Provinial STC Institutes	A Few				✓	✓	✓		✓	✓	✓	✓
Municipal STC Institutes	A Few				✓	✓	✓		✓	✓	✓	✓
Universities	✓	✓	✓			✓	✓	✓	✓	✓		✓
State Enterprises	✓		✓	✓	✓	✓			✓	✓	✓	✓
Spin-offs	✓				✓				✓	✓		
New High Tech Enterprises	✓				✓	✓			✓	✓		
Township & Village Enterprises					✓		✓		✓	✓		
Joint Ventures	✓			✓	✓							

One of the important considerations which affects the functioning of a national system of innovation is the extent to which the relevant governments can bring about an integration of their policies and funding programs in order to produce a positive policy environment which encourages entrepreneurial activity and technological innovation. The OECD countries, in a series of publications in 1990 emanating from a major program of research on Technology and Economic Policy, have concluded that the industrialised countries need to improve they ways in which their various programs and policies are integrated, one with the other. This is an approach which is easier to prescribe than to implement, and each country has to devise the system which is most suited to its own political culture.

In China, we have seen that at least four important commissions are active in either or both of policy formulation and program delivery in ways which are designed to promote S&T reform - and hence to stimulate innovation in the emerging 'socialist' market economy, but we have been unable to gain an insight into how their various activities are coordinated.

The Commissions involved are the State Science and Technology Commission, the State Planning Commission, the State Education Commission and the State Economic and Trade Commission. We do not know of any mechanism currently in place to allow a high-level interaction amongst senior officials of these bodies with a view to harmonising their interventions. Such interactions may already occur on a case-by-case basis, but we have no indication if they are effective. Even beyond this set of Commissions, there are a series of other Ministries which have interests in and policies for S&T, but we have heard of no forum in which these Ministries could participate in a full discussion of their interests in S&T. Furthermore, China has S&T Policy activities going on at the Provincial and Municipal levels, so the challenge of seeking some harmonizarion of all of the separate policies and programs is a daunting one.

Current Policy in China

From as early as the 1978 National Conference on S&T, the Govenment of China has been committed to a policy under which basic research should be permitted to grow gradually on a stable basis. The most recent, authoritative statement of Chinese policy for the support of 'basic research' is to be found in Section VI of the May 1995 "CPC Central Committee and State Council Decision on Accelerating Scientific and Technological Progress", entitled "Firmly Tighten Basic Research" That statement describes 'the missions of 'basic research' as being

> *"to explore natural laws, strive for new discoveries and inventions, accumulate scientific knowledge, establish new theories, and provide the new theories and methods for rebuilding the world."*
>
> *"to give priority to state-set objectives and consider it its central task to provide the power for national economic and social development......"*
>
> *"to proceed according to the principle of 'catching up in some but not all areas"*

and argues that it should

> *" stress key issues, pooling its resources on tackling those projects that will likely play a significant role in promoting national economic and social development".*

This mission statement could serve equally well as a statement of what the industrialised countries currently think of as 'strategic' or even 'pre-competitive ' research - that is of fundamental research, at the frontiers of knowledge, undertaken in areas of science which are considered to be of long term significance for future technological development. We will return later in this Chapter to discussing some of the implications of this articulation of this mission statement for 'basic research' in China, as seen from the vantage point of the industrialised countries.

The decision makes a commitment

> *" to continue to increase investments in 'basic research' ...[so that] funds for 'basic research' should gradually account for a larger percentage of research and development budgets"* [SSTC would like the share of GERD allocated to 'basic research' to grow from the current 6 or 7% to about 10% by the year 2000, by which time GERD is supposed to increase from 0.7% to 1..5% of GDP]

and goes on to argue that 'basic research' should be *"organically merged with the training of proficient personnel"*

One unique cultural feature of Chinese policy which has important effects in the area of basic research is the use of "eight-character phrases" to convey the essence of policies. This long tradition has become a source of a series of pithy slogans which institutions and individuals are expected to interpret and implement. In recent years, three such slogans have been coined to capture important policy initiatives; they are, together with the mission's own informal translations

- ***" wenzhu yitou, fangkai yipian"***
  "anchor one end securely, let the other roam free"
- ***" ding tian li di, hou lai ju shang"***
  " go forward with your head in the clouds, ~~and~~ your feet on the ground"*
  ~~FACING ECONOMY~~ Rely on S&T ~~Climb high MOUNTAINS~~
- ***"mian xiang, yi kao, pan gao feng"***
  "*start late, but end up ahead"
  "Facing the economy, rely on S+T to climb high mountains"

The first slogan is interpreted in different places, and at different levels, as meaning

- the government needs to secure the funding of certain important areas - including basic research - which are in the public interest but for which there is little market support; and, at a different level,
- institutes should support the best researchers with government funding and let the others look in the market place for support.

The second can be interpreted as calling for a strategic view to be taken of basic research - it should be innovative and at the leading edge of science, but in areas likely to have practical applications.

The third is an expression of Chinese determination to ~~become competitive in the world of~~ mobilize science ~~in at least some fields.~~ and technology to achieve great economic success.

Chinese activities in 'basic research' have been substantially affected by a series of significant reforms in the last decade of which, arguably, the most important was the creation of the National Natural Sciences Foundation (NNSF) in 1986. The founding of NNSF formalised the introduction of peer-reviewed, competitive project grant funding into Chinese 'basic research', replacing a former reliance on annual institutional budgets as the primary source of funding. In so doing, China has adopted an approach which is common throughout the industrialised world and which is believed by the industrialised countries to be an effective way of stimulating scientific activity of high quality. The industrialised countries are continuing to experiment with ways to inject the concept of 'relevance' and perceptions of the future importance of emerging fields of activity as criteria into the peer-review process.

NNSF had a budget of over 1,500 Million yuan RMB during the Eighth Five Year Plan (1990-95), and its annual expenditures have been growing faster than inflation in recent years. To allocate these resources, it has moved to put in place a set of funding programs designed to balance the objectives of providing the scientific underpinnings of national programs of social or economic development and of providing opportunities to individuals or small groups to pursue more speculative ideas. At present the foundation allocates the bulk of its funding to three categories of grants:

	Major Projects	Key projects	General Projects
Number of participating researchers	20 or 30 minimum; up to 100 in some cases	about 20 researchers per group	small groups or individuals
Duration of Grant	5 years	4 or 5 years	3 years
Share of NNSF Budget	about 20%		about 70%
Description of Activity	multidisciplinary; related to an economic or social goal	work at the frontiers of a discipline	researcher determined
Designation of Priorities	done periodically by large array of expert panels	related to areas of existing Chinese strength and to needs of High Tech Industry	researcher determined

Competition for NNSF grants is fierce, with only about one application in seven being successful. About two thirds of NNSF funds go to university based research groups, with the remainder going primarily to researchers from the Chinese Academy of Sciences.

Since early in this decade, NNSF has administered a fund (most recently of $US 4 million) contributed by the Ford Motor Company of the US to support research in areas of interest to the future development of the automobile industry - an example of a Multinational Corporation financing 'strategic research' in a developing country which had a combination of real research strengths and low costs of doing research

In one province (Guangzhou), the mission learned that there was a Provincial Foundation which had been established in 1987 and that it was currently being allocated a budget of about 10 Million yuan RMB per year.

In addition to creating and financing NNSF, the government had earlier begun, in 1984, to designate and finance of a series of "Key National Laboratories" - located primarily within a small group of universities and institutes of the Chinese Academy of Sciences - within which modern equipment for research would be installed and operated. Furthermore, government went on to designate a significant number of 'open' laboratories which were encouraged to promote cooperative activities in 'basic research' involving domestic and international scientists.

During the Eight Five-Year Plan (1990-1995) SSTC introduced the "National Basic Research Priorities Program" (the "Climbing Program") whose goals were to

- Gradually increase the (financial resource) input into basic research;
- support basic research through diversification [of funding channels];
- Train researchers, improve their quality and encourage them to work at the world frontiers of knowledge;
- Support open laboratories, improve working conditions, and generate a better academic environment; and
- Promote international cooperation and exchange.

A more recent initiative of SSTC is the creation of a small series of "National Research Centres" (possibly as few as ten of them) designed to combine the strengths of varying numbers of institutions of differing kinds in both 'basic' and applied research. These Centres will come into operation during the Ninth Five-Year Plan (1996-2000)

Observations from the mission

During our various meetings we received a variety of comments regarding the performance of basic research in China which give a flavour of the opinions of active scientists. We were told that

- many scientists appear to believe that there is
  * a shortage of funds, especially for long-term research;
  * individual research grants are getting smaller and are for shorter duration [but could this reflect, in the minds of some, a nostalgia for the less competitive system of the past?]
  * limited room for choice of research topic ;
  * a lack of non-governmental sponsorship for basic research;
  * a lack of rewards for groups which make contributions leading to widespread social benefit.

- there are other scientists who would argue that more able scientists today can get better funding for their work from NNSF than was available ten years ago, while less able scientists find conditions more difficult;

- the NNSF believes that there is a need to
  * improve the budget allocated to updating equipment and purchasing scientific literature;
  * continue to stress the need for young scientists to get into basic research
    [According to NNSF data, in 1986 only 1.5% of project leaders were under 35; in 1995 this had risen to 29%]
  * get more enterprises to support and engage in basic research.

- according to State Education Commission data,
  * 60% of all basic research is done in universities who receive only 4.7% of total GERD;

* 22% is done in the more than 5,000 research institutes belonging to the different levels of government; and
* 8% is done in enterprises (primarily in spin-off enterprises which were formerly parts of a research institution rather than in traditional state-owned enterprises.)

- a number of people interviewed believed that SSTC should devote more attention to the problems of research in the universities.

- there is widespread support for the idea that scientific research in the universities should be closely linked to the training function performed by those universities.

The huge number of institutions which exist today in China is a source of concern to policymakers and we in the Mission can identify one dilemma which relates to the role of the university system in research, particularly in 'basic research'. According to data which we received, China today has 1,058 universities, of which:

* fewer than 100 can claim to be 'research-intensive';
* about 200 have the right to grant Ph Ds, in at least some departments; and
* about 400 have the right to grant masters degrees, again in at least some departments;

According to data cited to the Mission by the State Education Commission,

* The top 50% of universities receive about 65% of all government S&T funding available to the universities as a group, and

* The top 100 receive approximately 80% of those funds.

The concentration of nationally-identified facilities is also very marked. From information provided to the Mission, we have calculated that there are 201 State Key Laboratories, Education Commission Laboratories and Engineering Research Centres operating in China today, with 100 of them being located in the top eleven universities, 20 of them in Tsinghua alone.

This already represents a very high degree of concentration and, given that these special facilities are designed to attract able scientists and be well-equipped, at least in relative terms, we would expect[1] that scientists from these universities would receive a significant share of the funding awarded by competitive grant by the NNSF. This leads us to question how much research content can there be in many of the universities which currently grant higher degrees but which are not among the list of research-intensive institutions? There is apparently a program (The 211 Program) in place to attempt to concentrate R&D activities in the top 100 universities, but the Mission was given no information

1 This statement represents a judgement on our part; we have not seen data on NNSF grants divided up by recipient institution.

on that particular initiative.

International experience suggests that doctoral level training requires that the departments which offer Ph.D. degrees must themselves be heavily involved in research. The same is not necessarily the case for undergraduate or masters level programmes. This experience would suggest that priority should be given in China to ensuring that all of its university departments which are authorized to award doctoral degrees should become thriving research departments.

Some people with whom we talked appeared to interpret current Chinese policy for basic research as meaning that it should be exclusively the activity of the universities and of a few institutes of the Chinese Academy of Sciences, CAS. We do not agree with that interpretation. We believe neither that 'basic research' should be confined mainly to the universities nor the converse that the universities should be involved solely in basic research. As we will discuss below, there are new forms of arrangement for strategic research which seem to us highly appropriate for China, in which a whole range of institutions can and should participate and in which there is ample role for the effective combination of research and the training of new researchers.

We have sensed that there is considerable debate surrounding the role of CAS within Chinese science, including within 'basic research'. People within the organization argue that basic research is 'having a difficult time' within the Academy and that younger scientists are moving towards the greater financial returns available in the market place.[However, we must ask how this observation can be reconciled with NNSF's contention that the % of team leaders who are under 35 has risen substantially in recent years.] However, outside the Academy there are those who wonder about its place in the new China. Some would ask if the long-term research conducted there might not equally be carried out in a university setting, which would render it more accessible to graduate training.

According to the Academy, the CAS has evolved away from an old Soviet model of an isolated set of basic research laboratories with no real contact with either universities (which, pre-1978 did little research) or with enterprises, into a system of national laboratories designed to

- ☐ provide a national base of competence in basic research, across the natural sciences, in a series of increasingly 'open' laboratories which host visiting scientists from across China and across the world (this includes CAS' special responsibility for China's activities in 'Big Science');
- ☐ provide advanced training to talented young scientists;
- ☐ participate in developing the most advanced high-technology sectors of Chinese industry; and
- ☐ undertake research which is broadly defined to be in the public interest (such as environmental science)

The CAS has developed a 'vision' of its own future which would see its workforce decline substantially from its present 50 000 scientific workers[2] (out of a total of 90 000 employees), operating in a 'one academy, two systems" mode in which selected basic research competence would be maintained using the government supplied budget, and an increasing share of the workforce would undertake applied tasks, financed by external sources.

CAS plays an important role in Chinese 'Big Science' and we were told that the State Planning Commission has approved an allocation of 700 Million Yuan over the next four years for a series of projects:

- An electron-positron collider in Beijing;
- A Heavy Ion Accelerator for Nanjing;
- A Synchrotron for Shanghai:
- some (unspecified) updating of an existing synchrotron in Hefei and
- A Large-Area Survey Telescope

However, we obtained no information on the processes of analysis which lead to this significant allocation of funds to Big Science and were given no information on the relative emphasis which China is likely to place, in the years ahead, on investments in national Big Science facilities in comparisons to financing Chinese participation in international projects.

Some Reflections on International Experience and Practice.

In a variety of industrialised countries, the use in policy discussions of the phrase 'basic research' is in decline. In Canada, for example, the national statistical organization has abandoned the attempt to accumulate data under the heading of 'basic research' on the grounds that the decision on what constituted 'basic research' was too subjective. This however does not in any sense represent a diminution of policy interest in supporting long-term research which is seeking a deep understanding of natural phenomena; it is simply a recognition that policy now addresses issues other than those which were in the past raised during analysis of different disciplines. In the industrialised countries, the phrase 'basic research' has come to embody a whole range of activities, including:

- so-called ***'curiosity-oriented' research***, often, but not always, carried out by individual scientists, searching for general scientific understanding rather than seeking to contribute to the solution of some pre-identified social or economic problem. Such research encompasses whole fields of science, such as cosmology and astronomy, as well as being practiced at the boundaries of knowledge in other fields in which the mainstream is already linked to application. The research supported in general shows little likelihood of contributing to economic development in any foreseeable time-frame. This type of scientific activity is giving rise to growing numbers of informal international networks of collaborating individuals and groups, their collaboration being

[2] We heard one suggestion that it should decrease to having only about 12 000 scientists on staff

facilitated by the inexpensive availability of electronic communications. The activity also provides a useful opening into the global scientific community.

- ***strategic research***, where teams of researchers, frequently from a variety of disciplines, explore the frontiers of knowledge in broad areas of science which are believed likely to be of future importance to economic or social importance; in this domain, the probability of some application is thought to be foreseeable in the medium term, even though the specific route to application at this time might be far from evident.

- ***'Big Science'***, of two kinds: first, that science, such as high-energy physics, which requires ultra-expensive facilities; and second, the geographically extensive research needed to understand changing global environmental phenomena. Both types of 'Big Science' are increasingly affordable only by consortia of countries who are prepared to share the considerable costs involved

Closely related to the concept of 'strategic research' is that of 'pre-competitive research' in which enterprises, which are competitors in the market, join together - often in research consortia - to undertake longer-term research projects which are both costly and technologically risky but in areas of research which could be of potential significance to their industries.

We have heard much discussion in China about the importance of 'basic research', but there always seems to us to be great vagueness about what actually is being discussed. We find the term 'applied basic research' particularly confusing. We can however see good justification for China remaining active in all three areas of scientific activity which we have just described.

One feature of current policy thinking in industrialised countries is the attention paid to understanding how research works in addition to giving consideration to what the objectives of research should be. The social organization of *scientific research*, and particularly of research which could be designated as being 'basic', as practised in the industrialised countries, differs from that of *technological development* in a series of important ways, summarised below. These differnet features influence the ways in which these activities are organised.

Characteristic	***Scientific Research***	***Technological Development***
Motivation	Intellectual: general curiosity about natural phenomena.	Economic or social: desire to solve specific problems
Attitude to information.	Operates on basis of wide dissemination of ideas and information to permit their validation. The "open scientific literature" is a key means of dissemination.	Often operates on the concept of ideas as proprietary knowledge. Will tend to use instruments of Intellectual Property as vehicles for disclosure.

Usual location of activity	Universities and Government Laboratories; a few large industrial labs.	Primarily in industrial laboratories in the private sector. (Difficulties are experienced when linkages to the user are weak)
Participants	A high proportion will have had doctoral-level training in a specific discipline.	Greater emphasis on practical experience beyond academic training.
Structure of groups	Traditionally, in many disciplines, this is the domain of the individual researcher, but this model is rapidly disappearing due to factors related to the increasing cost of facilities and the increasing potential for (electronic) networking .	More likely to contain an interdisciplinary mix of scientists and engineers; in some cases also there may even be economists or other social scientists.

The dominant features of the structure of contemporary scientific activity in the industrialised countries are described in the recent work of Gibbons, Limoges et al[3] who argue that

* knowledge is ever more produced in the context of its applications, and there are greater expectations that support of research will lead directly to economic and social benefits for the nation providing the support;

* there is an inescapable trend towards larger and more interdisciplinary teams working in more transdisciplinary research activities;

* there is a growing diversity of participating organizations to be found in today's research teams (there can be a blurring of project or program); and

* there is a continuing trend towards greater international linkages within research teams.

Such an attempt to explain a complex new mode of behaviour comes with its own built in contradictions. Debates can develop over the relative priority to be given to national versus enterprise interests, or about the nature of 'national' benefits to be derived from an 'international' program.

We have seen some evidence that the new organizational forms being introduced in China are

[3] Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow, " *The New Production of Knowledge* " London, Sage, 1994

designed to respond to at least three of these trends, with the exception being the relative lack of evidence of emphasis in China on transdisciplinary organisations. Many newer bodies - including the SSTC's National Research Centres[4] and Key Laboratories - still seem to be organised along traditional disciplinary lines and this, we believe, is a shortcoming.

We would pose a number of questions about the management challenges facing some of the proposed new National Research Centres and will use the Shanghai Research Centre for Applied Physics as an example to illustrate our point. Each of the participating institutions already have access to multiple channels of funding for their existing research activities and have ongoing projects in their fields of expertise. Will the Director of SRCAP have under his direct control enough *additional* funds to act as a lever to build in some coherence in to the research programs of the participating groups? Will the participants contribute some of their existing funding to make possible larger programs defined by the new Centre and its advisory Board? Will it be intended that any institution joining the consortium make an annual contribution to the research budget of the new Centre?

We ask these questions because we have heard that one unintended consequence of the reforms in research funding, in at least some institutes, has been to deprive the Institute director of most of his or her power to influence the direction and coherence of his/her institute's programs. This power, it is argued, is effectively now in the hands of the principal researchers for the external grants which now finance the institute's programs. The potential in consortia such as SRCAP for such an outcome is likely to be large, unless appropriate steps are taken to give management real responsibility for the Centre's work.

In the industrialised countries, where such centres are designed to undertake 'strategic research', great care is taken to ensure the extensive participation of representatives of enterprises from the industrial sectors expected to benefit from the research. A significant share of seats on the Centre's Boards of Directors would be filled by people drawn from enterprises, and most would have scientists from enterprises active in their research activities. The Mission has no information on whether the new Chinese National Research Centres will follow this pattern.

SRCAP is planned to group researchers from

- eight state key laboratories, {5 of which are university based and three are in CAS Institutes}
- six university laboratories {from 3 different universities}
- one joint laboratory {operated by the CAS and a fourth university} and
- six other CAS institutes

4 To be introduced during the Ninth Five-Year PLan

Background to the Reform Process

China has had a commitment to new science-based technologies since the 1950s but these had a chequered history through the period of intense development of military research and the disruption of the Cultural Revolution of the late 60s and early 70s. The reform process which commenced in 1978 has been directed to restoring that early commitment to the role of the science-based technologies as drivers of the civilian economy.

The National Conference of 1978 identified 108 key projects in 8 priority areas:

agriculture, energy, materials, micro-electronics, lasers, space, high energy physics genetic engineering.

This ambitious program was driven by the view that basic research was the well-spring for innovation (as in the old linear model formerly espoused in the developed countries) and by the need to rehabilitate scientists and engineers and the R&D system after the Cultural Revolution. New institutes were created leading to an increased expenditure on S&T in the government budget (1.5 %, 1.6% and 1.5% of GNP in 1978, 1979 and 1980 respectively).

It rapidly became clear that this approach was not producing in terms of short-term economic growth and that a more pragmatic approach to linking S&T to the economy was needed. The Key Technologies Program of the Sixth Five Year Plan (1980-85) identified areas of which only *agriculture* remained as a key area with another four being highlighted -

- *energy resource development and energy concentration,*
- *the raw materials industries and geological exploration,*
- *mechanical and electrical equipment and transportation, and, finally,*
- *new technologies and social development.*

Support for high technology continued into the Seventh Five Year Plan, adopted in 1981, and continued into the current Eighth Plan with a growing emphasis being placed on reforms leading to commercialisation of technological activities and to new modes of cooperation between the producers and the users of technology.

Significant features of the 'old' S&T system (developed in the period from the 1950s) which needed reform were

- the large number of institutes and S&T personnel at all levels of government in China,

- the lack of interaction between them because of their diverse reporting responsibilities and consequent duplication of activity (The Mission has termed this 'chaotic plurality') and

- their separation from the potential users of their outputs.

To illustrate the dimensions of this problem, in 1985 there were more than 4 900 'independent R&D institutes affiliated to government above the county level (county is an administrative unit of roughly 1/2 million people) with roughly 3,000 more at the county level.

In the former group, more than 2,700 institutes were engaged in industrial technology. It appears that the majority of the work done in these institutes was not R&D but much more oriented to supporting the state-owned enterprises which were weak in development capability and ~~not~~ less ~~encouraged~~ with the incentive to innovate. Paradoxically this assisted such institutes in the reform process since, once given more freedom of operation, they were able to transform into profitable businesses. The Mission saw several successful examples of this type of transformation at the provincial level (Examples are discussed later)

A significant group of research institutes associated with the Chinese Academy of Sciences (CAS), and a number with the Central Ministries and some provincial governments, were engaged in strategic research. These were seen as the spearhead of national efforts for transferring high technology into the market-place, with CAS leading the way.

Against the background, two significant trends have been

1 the massive importation of technology from overseas, to rapidly increase the production capacity, as a direct consequence of the 'open door' policy; and

2 the steady decrease of total expenditure on R&D by the government, leading to a national Gross Expenditure on R&D (GERD) of about 1.0% of GDP in 1988, ~~and~~ 0.71% in 1992 (~~it appears to have remained at this level to the present)~~. and .67 – 1993

Under the *'Decision on Reform of the Science and Technology Management System'* of 1985, this planned reduction in expenditure has been the instrument used to drive the reform process in the institutes, ~~and~~ Government expenditures on R&D as a percentage of the State Budget dropped by 14% between 1985 and 1986. Thus, from 1985 onwards, Government reduced allocations to the institutes and forced them into the market place. This reduction was not uniform and depended on the type of institute and its affiliation. Thus

- in the case of those institutes engaged in 'public good' R&D (such as health care, medicine, population control) in which there is little room to to obtain external funding, the reduction was only about 10-20 per cent (against the baseline of their 1987 budgets);
- in the case of agriculture which was seen as the highest priority area for the country, and again where there is a strong element of 'public good', the reduction was only 10 per cent;

- in the case of CAS institutes where the need was perceived to maintain a core of elite researchers engaged in fundamental research, the reduction was some 70 per cent while finally
- in the industrial technology institutes, particularly in the provincial institutes, the reduction was as much as 100 per cent. The timing of these reductions varied with the more draconian measures being introduced fairly rapidly.

Combined with increased autonomy for institute directors and increased mobility for researchers, the effects have been far reaching both in changing the culture of the institutes and in increasing their contribution to economic growth. This contribution is difficult to evaluate because of the influence of imported technology, but the Mission gained the impression that the contribution of high technology industries to industrial output had increased from around 2 per cent in 1985 to around 10 per cent in 1995 with the expectation that it would be 15 per cent by 2000.

These dramatic changes in funding have been complemented by other programs designed

- to maintain a capability in strategic research - for example the 863 and Climbing Programs
- to tighten the links to the application of R&D by the state-owned enterprisess -for example the National Key Laboratories Program and the concept of open laboratories, and
- to stimulate the setting-up of new enterprises -for example the Torch program.

Concurrently a technology market was created to legitimatise paid transactions in technology to enable the links to application to be facilitated. This new concept was critical to the reform process since the former system provided no grounds for market transactions in technology.

The Role of CAS in promoting High Technology

As noted above, the CAS was in the vanguard of the reform movement. With its 123 institutes and some 90 000 staff (of whom 50 000 were scientists and technicians, mainly in the natural and technical sciences,) it constituted a significant force in the Chinese S&T system. Prior to 1984, CAS had virtually no interaction with industry or with the universities which had a relatively low research base at that time.

However, a few far sighted individuals had already started to challenge the old system. Thus in 1980 the CAS Institute of Physics created the first technological entity that was not initiated, financed or owned by the State - the *Beijing Huaxia Guigu Information System Corporation Ltd* (now a Chinese-American joint venture). Other enterprises of this type followed in Beijing; most were very small but several rapidly became independent businesses, particularly in micro-electronics. The Mission visited ***San Huan Company*** in Beijing which had been developed in 1985 from the CAS Institute of Physics by a group working on rare-earth magnets.

San Huan Co, Beijing

San Huan began in 1985 when a group of professionals working on rare-earth magnets spun-off from the CAS Institute of Physics. Initially there were problems with patent rights with Sumitomo in Japan and General Motors in USA and production was restricted to the domestic market. In 1993 these problems were resolved and the company opened up export markets through a subsidiary San Huan International Trading Co. Production rose from 10t/year in 1985 to 230t/year in 1994 (with a turnover of 120 million yuan). The ownership is 84 per cent CAS and 16 per cent Institute of Physics.

San Huan has set up 6 subsidiary companies to increase production and to develop applications for rare-earth magnets in electric vehicles and scientific instruments. It has a world-wide distribution network and is the fourth largest rare-earth magnet company in the world. Currently there are 800 employed in the group of San Huan companies, including 100 in the Beijing headquarters. Of the latter, roughly 1/2 have come from the CAS Institutes of Physics, Electrical Engineering and Electronics. The company has its own research group of 10 people working on improved and new rare - earth magnetic materials.

These New Technology Enterprises (NTEs) as they became known tended to cluster informally together. initially in Beijing .In a parallel development, in 1985, the CAS moved to formalise such clustering by creating the Shenzhen Science and Industry Park as a co-operative venture with the Shenzhen Municipal Government. The aim was to establish a base where high technology from CAS and other institutes could be combined with foreign investment and technology to open a new way of commercialising high technology products. This concept has given rise, over time, to the creation of 52 high technology zones throughout China.

CAS and its institutes have now created some 900 NTEs of which roughly 500 are high-technology based with the other 400 being service oriented. Most are small but a number clearly have potential to expand. The Mission was told that roughly 10 per cent are very profitable, that about 30 per cent could be considered successful, with another 30 per cent fair and the rest failures. This accords with the general experience in the countries of the Mission members. These CAS NTEs employ some 20 000 people of whom roughly 10 000 are from CAS Institutes and another 10 000 on contracts. This is a significant movement of staff and clearly can be counted as a successful outcome of the reform process in changing the research culture.

A concern expressed to the Mission was that the CAS people moving out into the NTEs were the

1st time we have used 'fundamental'

basic basic

brightest and most entrepreneurial scientists and engineers and that, while short term gains may be made, there are potential long term problems for Chinese ~~fundamental~~ research. These concerns have been acknowledged by the State Science and Technology Commission with its programs to strengthen ~~fundamental~~ research. (There is in China, as in many other countries, a vigorous debate under way cancerning the appropriate role to be attributed to the universities in basic research)

basic

Again, the CAS has been farsighted by initially using some of its funding to promote ~~fundamental~~ research in the universities, in a set of experimental measures which lead to the creation of the National Natural Science Foundation in 1986. By its system of competitive peer reviewed grants, NNSF has stimulated research in the universities and also forced CAS scientists who seek support from it to be judged in the open market. Currently CAS scientists get about 30% of the grants.

(We were told that in Xian the CAS Institutes were not oriented to the solution of local problems.)

The Mission noted that, in Shanghai and Guangzhou, the CAS institutes located there had moved to direct their efforts to more local problems and to the support of local priority areas. ~~Thus,~~ In Gaungzhou the Guangdong Academy of Sciences incorporates the 10 local CAS institutes organized as the CAS Guangdong Branch together with other local institutes. Such cooperation is a model for other areas where the existence of unnecessarily large numbers of separate institutions has led to duplication and inefficient use of research resources. In Shanghai, a Shanghai Academy of Sciences has been set up including institutes of central and local government departments to give a coherent approach; there is a clear opportunity for the local CAS institutes of the CAS Shanghai Branch to participate, and this would seem to be desirable from the Mission's perspective.

A possibility expressed to the Mission was that the CAS institute structure should be dissolved and the institutes be handed over entirely to local governments to concentrate on local issues. The experiences of the Mission members suggest that this would not be in the national interest in the long term and that, while major restructuring may be necessary to streamline and redefine the mission of CAS, a core of CAS institutes provides the national strategic research resource which is essential for China's future development. The formation of National Centres, for example the Centre for Life Sciences in Shanghai funded by CAS, SSTC and universities, is an example of a new approach to the problem of more efficient use of research resources.

The Torch Program and Development Zones

The Torch Program was launched in 1988 by SSTC to build on the concept of technology parks initiated by CAS. Given the sluggish response by state-owned enterprises in accepting new technology (either by transfer of technology or by incorporating R&D institutes into existing enterprises,) the technology parks were seen as a new and dynamic thrust to bring hi-tech from the research institutes into the marketplace.

The Torch Program had as its major thrust the establishment of a number of development zones for new high-tech industries. This was supported by preferential tax treatment in the zone (15% instead of the national rate of 33%), special loans to finance new enterprises (various schemes were developed by provincial governments to encourage banks to co-operate) and preferential treatment for designated high-tech industries (essentially those defined in the 1978 National S&T Conference plus information technology, mechatronics and ocean engineering).

The number of zones has increased rapidly since 1988 so that there are now 52 National Level Zones with a wide geographical spread. These contain 10 000 NTEs employing 80 000 personnel and producing US$80 million worth of goods. This growth has been accompanied by the development of 60 Incubator Zones to assist individual entrepreneurs seeking to establish new enterprises. Not surprisingly there are considerable differences between the zones depending on their location and on the degree of support given by the local government. Some are located in urban areas with concentrations of R&D institutes and universities and are based on existing infrastructure with the aim of exploiting the potential of the available scientific and technical expertise. The Mission learned of such zones in Beijing and Shengyang. (Table 4.1). ?

Others include zones located in existing or planned industrial zones with clearly defined boundaries and extensive new infrastructure where there is encouragement for scaling-up hi-tech enterprises based on imported technology and capital. Thus the 5 Special Economic Zones and the Pudong New Area Development Zone include areas allocated to technology intensive projects. In the case of the Pudong New Area Zone, there is also a designated high-tech zone (Zhanjiang High-Tech Park) in the same area. The Mission had the opportunity to visit several such zones at Pudong, Xi'an and Anshan and was impressed by the scale of the developments and the range of industries located there. (Table 4.1).

The fact that it is becoming difficult to separate the exact roles of the activities in the development zones testifies to the success of the thrust of the reforms to set up high-tech industries as a significant industry sector in China. The large concentration of imported technology is clearly a significant factor in their success but there is also a notable contribution from domestic NTEs which have 'spun-off' from research institutes. In the future there is a need to ensure that there are more linkages developed in the zones between NTEs and overseas companies located there, possibly through new joint venture operations. It is likely that the preferential policies enjoyed by such zones will have to be phased-out when China joins the World Trade Organisation, but the Mission believes that the dynamism of the zones, as evidenced during their visits, will ensure their future growth.

Table 4.1: Cities with Zones for NTEs Visited by Mission

Zone	*No. of NTEs*	*Turnover*	*Employment*
Beijing	4 000 (1995)	7 billion yuan (1995) 25 billion yuan (2000)	29 000 (1991)
Shanghai	28 (1991)	700 million yuan (1991)	18 700 (1991)
Shengyang	250 (1991) 600 (1991)	360 million yuan (1991)	5 800 (1991)
Anshan	>150 (1995)	700 million yuan (1995)	???
Guangzhou	185 (1991)	1 440 million yuan (1991)	2 600 (1991)
Xi'an	200 (1985)	2.5 billion yuan (1995)	

Types of New Technology Enterprises

During its visits the Mission saw a number of different types of NTEs which had 'spun- off' from research institutes. Their characteristics depended on the parent institution, the local government and the nature of the technology involved in the 'spin-off' process. Clearly the Mission only had an opportunity to see some examples of a much more diverse group but these had some interesting lessons for the future. This is clearly a rich field for study by policy analysts and the Mission would encourage more detailed studies.

Form 1: *Part of an Institute spins off as an independent NTE*

This form seems to be associated mainly with 'spin-offs' from the CAS institutes and universities. It involves a piece of the organised structure (manpower, technological and frequently physical assets) of the original institution being diverted to establish a new business entity. This ensures that the NTE has a relatively strong starting point although there is no guarantee that this will ensure a successful commercial operation.

The Mission was given various examples of successful spin-offs during discussions but had the opportunity to visit the San Huan Co in Beijing (see Case Study, p 74) which is an excellent example of a spin-off from a CAS Institute initially funded by internal funds from CAS. Other CAS groups have spun-off to form joint ventures with funding from CAS and provincial governments (e.g. in integrated circuit production in Shanghai) or with foreign companies which provided capital and/or equipment to complement CAS inputs of people and/or technology (eg magnetic resonance imaging systems in Wushi)

Form 2: *An Institute transforms itself into an independent NTE*

This form seems to be associated mainly with provincial industrial technology institutions which have had their funds completely cut off over a period of 3 years and in consequence have been forced to change their mode of operation completely. This transition has been particularly difficult since the state-owned enterprises which formerly drew on their services for free have been reluctant to pay market price for their technologies. Such transfers of technology are often complicated by disputes over intellectual property rights which institutes are now seeking to enforce. In this regard the technology market has not yet begun to operate effectively.

The Mission was given several excellent briefings by chief executives of such organisations in Shengyang, Anshan and Shanghai. The examples covered a range of industry sectors namely

- in Shengyang - electronics, machinery (see Case Study p) and building materials;
- in Anshan, electrostatic technology and
- in Shanghai, light industry (see Case Study, p 78) and organic new materials.

Form 2: Shanghai Light Industry Research Institute, Shanghai

Established in 1958 as a research laboratory by Shanghai Municipal Government, it originally carried out research on behalf of light industries such as cosmetics, food, watch making, cameras, textiles, glassware, etc.

This Institute, just like all others in China, is state owned. Prior to the S& T system reform, its budget allocation consisted of core funding for salaries and benefits and project funding for researchers, was provided entirely from the government. It was staffed with bench-top researchers doing lab work without even a pilot plant for research results to be developed into prototype. During the reform process, the core funding was reduced to zero by 1991 (except the pensions for those already retired) and project funding was totally cut off by 1993. However, despite the adverse conditions faced by this Institute during the initial phase of the transformation, it has blossomed in the past 10 years.

The value of the annual business dealt by the Institute was raised from 1.17 million yuan in 1985 to 19.89 million yuan in 1994; the net profit was raised from 1 million yuan in 1985 to about 5 million yuan. The number of staff has also been reduced from 309 in 1985 to the current level of 210 with productivity increase from 3 800 yuan/head in 1985 to 23 000 yuan/head in 1995. Also, in 1991 it began to set up its first pilot plant for development of chemical products, an investment of about 5 million yuan, and in 1993 investment was made in another pilot plant for mechano-electronic processes. Furthermore, since 1992 the Institute terminated its traditional role of providing subsidised housings to new employees who are now assisted to purchase their own accommodations. All staff are on contractual basis with varying durations. Also prior to the reform 'reverse engineering' was widely practised by the Institute, but now it pays much attention to intellectual property right and severely penalises its staff for such infringements, even prosecuting them in court. It also trains its staff on ethical business practices.

According to the Directress of the Institute, who had taken courses in modern management techniques provided by Canada's McMaster University under CIDA funding, the key to the successes of the Institute's transformation during the reform in the past 10 years was innovation. The entire Institute was engaged first of all in attitudinal innovation, which in turn led to technical innovations, organisational innovations and innovations in personnel management.

No case study No. 3.

These discussions brought out a number of common themes namely: the success of the transition depends to a very large on the entrepreneurial ability of the chief executive; the dual leadership role imposed on chief executives by the heavy burden of social responsibility for his workers (both present and retired) coupled with technical leadership causes many tensions: the failure of technology markets with local SOEs forces the transformed enterprises to seek markets elsewhere in China and overseas and finally national recognition in some form is a considerable asset in the marketplace.

Form 3: *S&T personnel move as individuals to create independent NTEs*

This form arises when scientists and engineers move, individually, from their previous R&D institutes. They move out with embodied knowledge as their primary resource, together with experience in R&D and design and innovative ideas. Their basic problems arise from obtaining finance, although this is becoming easier as provincial authorities set up mechanisms to give start-up grants and to assist with low interest loans. Thus, in Guangdong, the Mission was told of the activities of the Guangzhou Technology Corp Ltd set up by the Guangzhou Science and Technology Commission.

Unfortunately the Mission did not have an opportunity to visit any such companies but were told in Shengyang that some 60 per cent of the 600 or so NTEs in the Nangpo Development Zone had been set up by individual researchers, largely from the local CAS Institutes and universities. The role of the universities was reinforced during discussions in Shanghai where Shanghai Jiaotong University noted that there were 168 spin-off companies founded by its staff, with sizes ranging from 4-5 people up to 300 people. Here the University has assisted with venture capital and management and claims to be receiving 100 million yuan in revenue from its investments. Among the more successful of these spin-offs, three have gone public to seek further capital for expansion.

Form 4: *Linkages of Institutes with TVEs*

Township Village Enterprises (TVEs) have developed an interesting range of linkages with research institutes. Given that TVEs overall constitute between 40 to 50 per cent of the total economic output of China, and that in many cases they have moved rapidly in to many advanced technology areas - often well ahead of SOEs - their linkages with institutes deserve special consideration. For the new TVEs the pressure to compete is driving them towards alliances with research institutes. For their own survival and development, the research institutes are driven towards the TVEs as willing and receptive innovation partners.

The range of products and processes covered by TVEs is not limited to the production of agricultural products. As the Mission learned in its discussions, depending on location, 50 to 70 per cent are engaged in textile production, building materials, plastics and electronic components. It appears that they are often small but dynamic (because of their collective ownership) and so TVEs are better able to sense market demands and opportunities to use technology developed by institutes then are the larger and more conservative state-owned enterprises. The links are often established by individual researchers from institutes seeking to augment their salaries by external contracting or by family linkages. The transfer of tacit knowledge in this way can lead to issues of ownership of intellectual property but can also lead to growth of TVEs. Several successful examples were described to the Mission (see case Study).

Form 4: Xiangyang Chemical Factory, Liaoning Province

The Factory was set up in 198, with 7 employees and capital of less than 1 000 yuan, to manufacture wall paint as a Township Village Enterprise in Yingkou township. In 1987 it made contact with the CAS Institute of Chemistry in Beijing as a result of the links of a Professor there with the village. Powder coating materials for domestic appliances were developed jointly and, with a resulting high quality product, production and profits grew rapidly (from 650 000 yuan in 1987 to 14 million yuan in 1989).

In 1989, the Factory and the Institute jointly established a new company to manufacture a new organic catalyst developed by the Institute. This has grown rapidly to a production of 8t of catalyst in 1995 with sales value of 30 million yuan. The Factory now employs 262 people and has fixed asset capital of 10 million yuan. It is planning to expand production to 20t pa using investment capital from a bank loan of 6 million yuan and self funding of 4 million yuan. The Institute is supporting the development of new catalysts for a contract fee of 600 000 yuan per year.

The 863 Program

While the Mission did not have an opportunity to see any practical aspects of this Program, it is important to briefly describe it in order to understand the degree of China's commitment to high technology. The 863 Program (so called because was established March 1986, as a result of a proposal by four eminent scholars) is a medium to long-term plan for the development of high-technology in China. It stemmed from the concerns of researchers to maintain a high quality fundamental research program at a time when policy was heavily oriented towards the application of S&T for economic growth. The resulting activities would be referred to as 'strategic research' in the industrialised countries.

The Program emphasises development of 'start-of-the-art' technologies in 7 areas -

biotechnology, space technology, information technology, laser technology, automation, new energy sources new materials.

(These are similar to the areas identified in the 1978 National S&T Conference). Under the overall guidance and funding by SSTC, there are more than 13,000 scientists and engineers engaged in the

Program, through a series of networks and involving a number of newly established research centres. These include the Computer Integrated Manufacturing Systems Engineering Research Centre, the Intelligent Robot Research Centre, the Photo-electron Research Centre, the Genetic Engineering Drug Research Centre, the Artificial Crystal Research Centre, the Genetic Engineering Biological Products Research Centre and the Genetic Engineering Vaccine Research Centre. The relationship of these Centres to the large number of other specialised research centres in the country is not clear to the Mission and superficially these would appear to be substantial overlap in a number of fields.

Five of the 7 areas is under an area office located in SSTC (the other two fall under the jurisdiction of the Commission for Science, Technology and Industry for National Defence, COSTIND) and activities are co-ordinated through an expert committee for each area drawn from leading scientists in CAS, the universities and appropriate Government departmental institutes. Stress is laid in the Program on

- bringing together the brightest young researchers in China together in the Centres,
- encouraging Chinese scientists overseas to return to the Centres and
- using the Centres to link actively to international science and technology.

Military Technology.

Chapter 5 S&T Reform and the State-owned Enterprises

The state-owned enterprise sector

The state-owned enterprise sector in China constitutes an enormous share of the national economy, accounting for approximately 43% of China's gross value of industrial output (down from 78% at the beginning of the reform period in 1978).[1] The State-owned enterprises still provide some 70% of the industrial jobs at or above the county level in China, in spite of the rapid growth in employment opportunities associated with the TVEs.

There are some 104,700 state owned enterprises out of over 9 million Chinese industrial enterprises (the great majority of which are private), most of which are controlled by provincial or sub-provincial level governments. Some 14,000 of the State-owned enterprises are classified as "large and medium sized" enterprises and form the core of the state industrial sector, accounting for about 80% of total State-owned enterprise output and 35% of the total industrial output. Of these, 2,000-3,000 are considered to be "very large." State-owned enterprises supply the major share of tax revenues to different levels of the state, constituting 65% of government revenues in 1993.

THE STRUCTURE & WORKFORCE OF THE ANSHAN IRON & STEEL COMPLEX

Company Element	Workforce
Iron & Steel Production	70 000
2 Iron Ore Mining Companies	30 000
Mechanical & Machine Building	15 000
Electrical Manufacturing	10 000
2 Construction Companies	20 000
Railway Transport	10 000
7 Research Instututes	1 000
Staff Welfare Organizations	10 000
8 Hospitals	10 000
Education (up to College)	9 000
Housing system	??
Policing for Anshan	??
The Total Complex	**190 000**

While not all State-owned enterprises are unprofitable, it is likely that as many as two thirds are. In 1993, losses from the State-owned enterprise sector were estimated to be 2.4% of GDP for State-owned enterprises of all kinds (down from 5.3% in 1990). For State-owned enterprises in the industrial sector, the figure for 1993 was 1.4% of GDP, down from 2% in 1990. The state's explicit subsidies of these losses has been declining. However, there has been a growth of implicit, "quasi-fiscal" subsidies in recent years - typically through "policy loans" through the People's Bank of China - and these are thought to have grown to between 5.1 to 6.8% of GDP by 1993.

[1] Unless otherwise noted, this background discussion of the State-owned enterprises is drawn from Harry G. Broadman. "Meeting the Challenges of Chinese Enterprise Reform." Washington. The World Bank, World Bank Discussion Paper 283. 1995

In the period since the initiation of reforms, many large and medium state owned firms have made progress in improving their technology and management as a result of technology imports, greater attention to domestic sources of technology (especially "in house" R&D) and the pressure of market competition. Those which have taken the business of reform most seriously seem to be those whose technology levels have improved, although other factors (such as firm size, industry type, location, etc.) also seem to have been important. However, according to one recent study, industrial growth still seems to be driven mainly by new inputs of capital and labor; the old patterns of extensive growth still seem to prevail. This pattern of growth is no longer sustainable, and will become even less so once China becomes a member of WTO.[2]

THE SHENYAN BLOWER WORKS
- A Successful State-owned Enterprise-

The Enterprise is one of the world's top ten producers of turbine -compressors, blowers and fans;

It has recently attained ISO-9000 certification;

In association with a CAS Institute and six Chinese Universities, it has developed and put into operation a highly successful Computer Integrated Manufacturing System (CIMS);

It does its own product design and develops highly sophisticated software for its CIMS system with its Chinese partners, but it imports the most important computerized machine tools from the industrialized countries.

It pays great attention to worker training, sending staff members abroad each year to become accustomed to the most modern techniques; the entry level for employment is equal to college entry level and all of its machine operators get a three year training course plus regular updates.

It demands quality products from its suppliers and has even purchased castings from the USA when locally-fabricated castings failed to meet its specifications.

A key element of its success has been its entrepreneurial management.

Until quite recently, State-owned enterprises continued to operate according to a planning system, and have been confident that the state will cover their losses. Until recently, they were still giving bonuses to their workers and continuing to neglect innovation even in the face of losses. Policies for industrial technology have not been carried out. For instance, State-owned enterprises are expected to devote 1% of sales to technological improvements; few do. The lack of commitment to technological improvement has also led to capable technical people leaving the State-owned enterprise sector for new, high-technology enterprises, township or village enterprises, joint ventures, and wholly owned foreign companies. The movement in personnel can also be understood in terms of the reward structure for scientists and engineers; status and pay are low and according to one survey, bonuses are typically 15% lower than those for ordinary workers[3]

There appears to be an important issue concerning which types of technology should receive

2 See Science and Technology Commission of the Chinese People's Political Consultative Conference "*The Problems and Proposals Concerning Technological Progress in Large and Medium-sized State-owned Enterprises*", Forum on Science and Technology in China, Vol 1 No 1, June 1994, p 42

3 (CPPCC, *op cit*, p. 45)

attention. Much focus has been given to advanced technology, and this has led to parts of the industrial technology system of an enterprise becoming fairly modern. However, attendant technologies (eg., for parts and components) often lag behind. There is also the question of whether an industry should strive for a general technology upgrading, with efforts made to bring other enterprises up to the level of industry leaders (through pro-diffusion policies, for instance), or whether the strengths of the leaders should be enhanced, for instance, to meet international competition.

State-owned enterprises are products of the prereform planning system and the regulatory and management policies of that earlier era. At the beginning of the reforms, most had also suffered from policies and management styles which discouraged technological innovation. As a result, most were characterized by seriously outdated technologies. In addition, most State-owned enterprises carry heavy social services burdens and have redundant labor forces, typically 30-40% greater than needed. Recent studies have estimated that social services constitute about 6% of the total costs of the average urban State-owned enterprise, and account for 40% of its wage bill. These heavy social service burdens both contribute to the difficulty of achieving successful enterprise reform and also help explain why the state is reluctant to allow State-owned enterprises to wither and die.

At the Anshan Iron and Steel Works (Angang), for instance, total staff now numbers about 190,000. Angang's restructuring plans call for the shedding of ancillary enterprises and social service organizations in order to reduce staff in the core steel making business to about 70,000. Assuming that its annual steel making capacity is raised to the projected 9 million tons, it will still be competing against international firms who on average produce the same amount of steel with about 15,000 staff. It is clear from the Angang case - admittedly an unusually large and complex State-owned enterprise - that many of the problems with State-owned enterprises are not in the first instance technological ones. Indeed, before modern technologies can hope to improve the performance of many State-owned enterprises, the larger problems of managerial, structural, and social reforms must first be solved. As one recent analysis has put it,

> *"Preliminary experience drawn from reform practices has shown that a lack of technological dynamism is a manifestation of a much larger structural problem that cannot be solved by any shortcut or through any simple policy instrument alone. Successful industrial technology development is a result of the interplay of many factors."* [4]

For many State-owned enterprises (perhaps one third), the chances of survival are so marginal that the state is prepared to allow them to go bankrupt and/or be sold off. For perhaps another one third, although they are losing money, there seems to be a commitment to save them. For the one third, or so of profit making enterprises, the challenge is to upgrade them through managerial reform and

[4] See Xu Zhaoxiang, "*Policy and Institutional Priorities for Industrial Technology Development: China*", Forum on Science and Technology in China, NRCSTD, Vol 1, April 1995,p 83

technological change in order to make them internationally competitive.

Necessarily, then, State-owned enterprises loom large on the state's agenda. Because of the variety of firm sizes and the variety of industries they represent, and given the great social and economic complexity changing them represents, identifying and making the right policy choices to deal with state enterprise problems, has not been an easy task. While the strategies continue to evolve, they have involved the following elements:

- ongoing waves of enterprise management reforms,
- broader economic and social reforms pertaining to the environment in which the enterprise operates,
- ambitious efforts to upgrade the technology of enterprises through the procurement (often from abroad) of advanced production technology and
- S&T reforms intended to bring Chinese R&D efforts to bear on the technical needs of the State-owned enterprises.

These strategies are interrelated and it is difficult to discuss S&T reforms pertaining to State-owned enterprises without also discussing the other elements in the strategy.

This is not the place to attempt a complete review of the reform environment of State-owned enterprises. Suffice it to say that there has been an evolution in reform thinking from early efforts to enhance managerial authority while gradually introducing market mechanisms, to the introduction of the contract responsibility system, to the growing realization of the importance of economic legislation, to a realization of the importance of clarifying property rights which in turn required a more careful inventory of state assets. With better accounting of assets and attention to property rights, attention began to turn to control and mobility of these assets and to a share holding system. The 1992 "Regulations on Transforming the Management Mechanisms of State-Owned Industrial Enterprises" nominally extended 14 new "rights" to enterprises to enhance their autonomy and authority. Relatively few enterprises have, in actuality, been ceded all 14 rights, but the downward devolution of authority has nevertheless been substantial as was evident from discussions during the Mission.

With the March, 1993 introduction of the concept of "socialist market economy" as the guiding principle of economic philosophy, and the "Decision on Issues Concerning the Establishment of a Socialist Market Economic Structure" taken at the Third Plenary Session of the 14th Party Congress in November, 1993, a new surge of reforms is transforming the context in which discussions about the future of State-owned enterprises should occur. In particular, policy support for the idea of a "modern enterprise system" is opening up possibilities for diverse ownership schemes, significant industrial reorganization leading to large national corporations and conglomerates, and changing relations between government and industry which are intended to separate state ownership rights from the operational property rights of the enterprise/corporation as a legal person. For such reforms to go forward, additional reforms are necessary in macro economic and monetary policy, further expansion and liberalization of labor and capital markets, the implementation of a social security system, and the full implementation of a legal system suitable to a market economy.

In 1994, 100 enterprises were selected for full "corporatization" within two years. Under the leadership of the State Economic and Trade Commission and the State Commission on Restructuring Economic System, this corporatization will involve the conversion of the selected enterprises into limited liability and limited liability share-holding companies, the settlement of their outstanding debts, concessional bank financing, income tax concessions, and a reduction of their social services burdens (Boardman, p 26). At least one of the enterprises visited by the Mission (the Yanshan Petrochemical Plant) is included in this experiment.

The changes noted above were going on during the period of the Mission, but were not its primary focus. However, what was clear was that there were fundamental changes at work in some of the enterprises visited, and that these were transforming the challenges of technological innovation and R&D in fundamental ways. Enterprise reform was not the primary concern of the Mission, and as a result we did not have meetings with the appropriate agencies charged with the cardinal restructuring tasks.

S&T Reforms and the state-owned enterprise sector

What was clear, however, was that given the enormous implications the technological upgrading and industrial restructuring have for national S&T policy (nominally, the domain of SSTC) and given that these tasks fall more into the hands of the other commissions (especially the State Economic and Trade Commission and the State Commission on Restructuring Economic System), it was understandable why a number of our interlocutors bemoaned the fact that national S&T policy is fragmented. It was also clear, that as Chinese enterprises are being restructured and reorganized, and their relations with the state changed, science and technology are coming to articulate with the needs of Chinese industry in ways that are more reminiscent of firms in a market economy than with enterprises in a socialist planned economy. This fact again points to the quandary of how to approach the development of policy and coordinating mechanisms within the national government for a marketizing economy in which R&D spending by enterprises is expected to become the main source of GERD.

In addition to domestic economic and management reforms as factors shaping S&T in State-owned enterprises, the open door policy has also had a major impact on the State-owned enterprise sector. This impact comes in two forms.

- First, with Chinese enterprises increasingly participating in the global economy, and with the growth of foreign business activity in the Chinese domestic market resulting from the gradual liberalization of Chinese foreign trade policies, State-owned enterprises are facing market competition in ways which never occurred in the pre-reform period. This has begun to create incentives for improving enterprise technology and, thus, to reverse the attitudes and behavior from the pre-reform period. The pace of this change is often less than might be desirable, but it was evident in all the firms visited during the mission.

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- Second , in conjunction with the first point and with other reform policies, the open door policy has led to the acquisition by Chinese enterprises of massive amounts of technology from abroad. Shanghai alone has spent about $US 20 billion on imported technology since the late 1970's, and estimates for the whole country are in the neighborhood of more than $US 40 billion. This surge of imported technology, plus the technology upgrades from domestic sources, has had the effect of making the technological levels in many State-owned enterprises considerably more appropriate for market competition than had been the case before these programs of "technological renovation" (*jishu gaizao*) were begun. Still, on average, the technological level of State-owned enterprises is well behind 1990s international standards, and the need for ongoing technological upgrading continues to be a pressing matter.

Examples of successful technology enhancement in China viewed by the Mission (and which are consistent with experience in other countries) have involved the introduction of foreign technology from abroad which was then complemented by local research and development to facilitate the full and effective assimilation of the imported technology, and to provide for the complementary technologies and technical services which the major piece of technology from abroad would require. While successful transfers in China have had profound effects on the quality, price and overall competitiveness of Chinese industrial products, there is also evidence that there has been less attention to this area of policy than there might have been. It has been observed, for instance, that, on average, for every 100 yuan RMB spent on procuring technology from abroad during the 1980's, only 9 yuan was spent on absorption and assimilation. This is in marked contrast to South Korea and Japan, where major R&D efforts were made to assimilate imported technology[5].

[5] (CPPCC, *op cit* p. 48)

The pre-reform technological backwardness in State-owned enterprises was not only a function of an economic system which discouraged innovation, as noted above. It was also a function of the design of the S&T system. To this day, most State-owned enterprises are organized and led by production ministries (or production bureaus at local levels). These ministries also have their own free-standing R&D institutes as well, supposedly to serve the enterprises under their ministry, as in the Soviet model. Most of the 5,000 plus Chinese research institutes at the county level or above - and thus, most of China's scientists and engineers in R&D were found in institutes of this sort. While some very large enterprises have had their own "in house" R&D capabilities, and as a result of the reform policies, many other large and medium sized enterprises are beginning to establish them, most State-owned enterprises do not. They were intended to rely on the work of the free-standing ministerial (and industrial bureau) institutes to meet their S&T needs. Similarly, technical personnel for both research and production were to come from specialized institutions of higher education which were also part of the ministerial "system" (*xitong*).

LIAONING PROVINCIAL MACHINERY RESEARCH INSTITUTE

-From Institute to "Virtual Corporation"-

In 1990, the Institute's fixed asets were evaluated at 6.7 Million yuan and the Government contribution to its budget was reduced to zero. Today its fixed assets are estimated to be 31 Million yuan and it pays salaries far above the provincial (and national norm ($US 3 000 per year on average, with the top scientist earning $US 20 000)

In 1995 it will derive 50% of its income from the sale of equipment it has designed for a variety of industries (eg Food Processing, Environmental Protection, Air Conditioning) and expects this share to go up to 60% next year.

The other income is from R&D contracts and from technology licensing. It has had no success competing with national institutes for national contracts so deals virtually exclusively with enterprises.

It manufactures in its own pilot plant and factory (which employs 200 people) and through an extensive system of subcontracting to local factories, some of whom are completely dependent on the Institute for their continued existence. It would never consider buying a state-owned enterprise because of the burden of social welfare costs it would acquire.

It is now establishing its own small offices overseas (eg in Kuala Lumpur) to explore foreign market opportunities

The local Liaoning Machinery Bureau still has the right to appoint the Institute's director and can require the institute to pass over funds to the Bureau.

A chronic problem with this system was the failure of the research subsystem to articulate with the production subsystem. As a result, technology in enterprises was not being infused with new ideas from the laboratory and new technologies from pilot plants, and research in the institutes stagnated, having neither effective demand from the economy for new research directions nor a stream of new personnel from outside the closed ministerial system. More generally, two very different cultures grew up in the two subsystems which worked against collaboration and cooperation.

As seen in Chapter 1 of Part 2 of this Report, a central objective of the S&T reforms has been to overcome this separation of research from production with the introduction of a number of reform policies. These included the introduction of a labor market for scientists and engineers, and the introduction of technology markets and research contracting (requiring in turn a fundamental reconceptualization of intellectual property and the establishment of a patent system). More importantly, however, the introduction of market competition via the more general economic reforms began to stimulate demand for new technology, and the major changes in the funding of research (and the dimunition of guaranteed appropriations to research institutes) has forced a fundamental change in the character and behavior of research institutes. In spite of some successes, the widespread persistence of many of these problems in the mid-1990's indicates that reform efforts have not been fully successful. Given the complexity of the problems, this should not be surprising.

While some progress has been made in overcoming the separation of research and production as a result of the growth of contract research and technology markets, it appeared to the Mission that there were far more fundamental changes going on which were made possible by the reform environment, but which were not entirely anticipated. The S&T reforms, especially funding reforms, seem to have had greater impacts on the institutes than on State-owned enterprises. The initial experience in the late 1980s with technology markets seemed to run afoul of the inherent difficulties of placing a value on technology and on the weakness of demand for technology coming from enterprises which until quite recently had yet to face up to the realities of market competition. In the face of such problems, other policies were tried which attempted to encourage the merger of enterprises and research institutes. The diverging cultures of the two types of organizations and the difficulties of managing all of the social welfare implications of such mergers, have limited the effectiveness of this policy as well.

The acceleration of economic and management reforms and the widening of the open door in the early 1990's, however, have created a new environment for the linking of research to production, and most importantly, has created conditions for a variety of institutional innovations which promise considerable benefits for Chinese industry as a whole, including State-owned enterprises. On the basis of the mission's observations, these fall into three categories.

1. *The "enterprisization" (**qiyehua**) of research institutes.* During the course of the mission, we had opportunities to observe the responses of a number of industrial institutes (under either central ministries or local industrial bureaus) to the drastic budget cuts they had experienced and to the new market environment. While the cases we saw were of successful institutional innovation, they clearly indicated that under the right reform conditions, reform objectives can be met. While not all of these cases involved the formal transformation from a research institute to a company (***gongsihua***), in all cases, the organization involved had successfully found an economically useful role - as consultancy, technology broker, engineering services provider, manufacturer, etc. - which did not exist and often was needed in the pre-reform, state-owned-enterprise-dominated industrial economy. Common elements of success seem to include technical capability, a supportive policy/political environment created by local authorities, and most importantly,

entrepreneurial managerial leadership.

2. *Joint venturing between research institutes and factories* based upon clear market objectives and market needs, and on realistic understandings of the value of the assets which each party contributes to the new venture. Enhanced market intelligence, and progress in thinking about intellectual property and share holding systems make ventures like these profitable and sustainable in the 1990s in ways which were not possible in the 1980s.

3. *"Open" approaches to technology acquisitions.* Cases where technology seemed to be making a differences in the economic vitality of State-owned enterprises were characterized by a very open and diverse approach to the acquisition of technology. Except for firms which had very specialized technologies developed in China, most of the other successes had relied heavily on imported technology but had supplemented this with Chinese technology and their own R&D. Special efforts to assimilate the technology paid off in both launching the enterprise on a more sustainable trajectory of positive technological change, and created an enterprise culture that was welcoming and appreciative of technological innovation. These firms were typically already spending more than the national average on R&D, and although in house research was going on, success also seemed to be characterized by participation in networks of R&D activities which brought together complementary talents from the firm itself, and from research institutes and institutions of higher education from both inside and outside the ministerial system. These "open" approaches - mixing "make/buy," "search/research," "domestic/foreign" distinctions in new ways - are characteristic of international trends, and the participation in research networks of different organizations having complementary S&T capabilities is consistent with current thinking about new approaches to the production of knowledge.

These impressions of apparently successful cases have implications for future policy development. At stake here is the implementation of a modern national system of technological innovation to replace one that had been built on faulty or outdated assumptions from the past. The implementation of such a system, however, depends on a number of things which are beyond the normal reach of S&T policies. These include the broader context of economic reforms (especially with regard to prices, taxation, property rights and other areas of business and commercial law, foreign trade, etc.), industrial structure and enterprise organization, and enterprise management. In light of these factors, and considering the size and diversity of the overall industrial economy, it is very difficult to design a single set of S&T policies - including S&T reform policies - for State-owned enterprises as a whole.

It is clear that many of the S&T reforms and policy initiatives are going in the right direction. In addition to those noted above, the recent SSTC programs on industrial extension and technology diffusion and on promoting nationally linked productivity centers are likely to produce important benefits, especially to small and medium sized firms. But as with other programs, they are premised on enterprises giving rise to effective demands for new technology .

Issues for the future:

1. If China's GERD/GDP ratio is to reach the 1.5% figure that has been targeted, the spending on R&D by State-owned enterprises will have to be increased significantly. This fact raises a number of questions.

- First, it is likely that government policy will be required to induce enterprises to meet the increased expectations placed on them. The Mission heard mention of special tax incentives, for instance. It is clear, however, that there is a danger that such incentives will mean little more than increased "tax expenditures" by government, rather than true increased R&D expenditures by enterprises. The trick in designing incentive programs is to induce incremental spending by the enterprise sector.

- Second, assuming the enterprises can be encouraged to increase their R&D expenditures, who will do the work? Increased "in house" research would, in principle, be desirable. However, since relatively few State-owned enterprises now have their own R&D facilities and traditions, it may be difficult for them to organize and staff up in order to do quality work during the period of the 9th Plan. This suggests that there may be a need for highly innovative approaches for State-owned enterprises to work with parties outside of the enterprise in networks of researchers and innovators. We have already identified this pattern as one that is working in China in some successful cases. It may imply that special attention to the management of innovation - including, but not limited to high quality in house research - in enterprises is necessary.

- Third, the development of R&D strategies for State-owned enterprises will be occurring in a highly fluid and unsettled organizational environment brought on by corporatization. There is likely to be a great deal of confusion about ownership of all sorts of assets, including intellectual property. Should intellectual property be considered as belonging to a company, to a conglomerate, to a supervising ministry, or to a holding company? It is quite possible that ambiguity over IPR in the context of organizational change could be a significant deterrent to the expansion of the R&D expenditures by enterprises.

- Fourth, the appeals of acquiring advanced foreign technologies, either through Sino-foreign Joint Ventures or independent of them, will continue to be strong. In some ways (though not in all), these technology acquisition strategies have worked to the advantage of State-owned enterprises but against the objectives of domestic R&D policies. This is likely to be the case in the future as well. In order to achieve a balance between the advantages of technology transfers from abroad and domestic R&D, there is a need for sophisticated policy mechanisms for coordinating technology imports and R&D. In part, these are to facilitate the absorption and assimilation of foreign technology. But, perhaps more importantly, they are needed to set realistic priorities to insure that R&D resources are not wasted on projects which, even if successful, yield technologies which would be behind international levels. Such mechanisms will require new forms of government-business cooperation to insure that both the short term needs and perspectives of firms facing the market are reconciled with the concerns of the policy maker and the research community for the scientific and technological well being of the nation over the longer term.

- The emergence of new high-technology enterprises and of research institutes which have successfully suffered through the agonies of reform and are now profit making enterprises, represent new forces in China which can serve many of the technological and engineering services needs of State-owned enterprises, helping to fill gaps between the productive and engineering capacities of the State-owned enterprises and the needs of customers. These new creations can also be seen as possible competitors of State-owned enterprises in some industries and as having interests in S&T policy outcomes which are different from State-owned enterprises. Maintaining a policy environment which will both maintain creative competitive tensions while also stimulating useful synergies between the two sectors will be a challenging, but worthy objective of policy.

As noted above, the challenges posed by the State-owned enterprise sector go far beyond the normal concerns of S&T policy. While the latter should be focused on questions of aiding the transition of State-owned enterprises to profitability through technology driven productivity gains and new product mixes, there is also something to be said for a proactive stance for S&T policy in the State-owned enterprise sector. From this perspective, the attention is less on the transitional issues than on what to do with S&T in the successfully reformed State-owned enterprises. Since it is assumed that these will be market competitive firms with high degrees of managerial autonomy, fresh thinking about their S&T needs will be required. New terms of reference will be required, with concepts like "corporate R&D and innovation management" replacing "State-owned enterprise S&T activities," and where the idiom of policy will shift towards the complexities of "government-business relations" in a market economy.

Chapter 6: The Impact of S & T Policy Reforms on Agricultural Research and Rural Development

Introduction

Agriculture is arguably China's most important economic sector and in 1990 accounted for 20% of GDP and 60% of the total employment in the country. With only 7 % of the world's arable land, it has been responsible for feeding 22% of the world's people . The performance of this sector is therefore vital to China's food security and the basis of the living standard of a major proportion of the country's population.

Over the last 30 years, despite the difficulties experienced by the agricultural research system during this period, the investments in research have been responsible for 20% of the increase in agricultural productivity[1] For these reasons the further development of the agricultural research sector has been given the highest priority in the eighth five year plan and also the most recent S&T policy reforms which are designed to strengthen the agricultural research effort through the more effective transfer of new technology, to the farmers and to the town and village enterprises (TVEs), developed under the Spark program.

The Policy Agenda for Agriculture

The May 1995 policy statements on accelerating scientific and technological progress have, as one of their major objectives, the development of a more efficient, modern agricultural system, through the application of advanced equipment and agrotechnique, to meet China's future food requirements through stimulating the :

- integration of agriculture science with education to popularise agricultural science and technology and to assist in the integration of technology and industry as a priority in the development of the rural economy
- strengthening the quality of scientific research and technology in agriculture and improve agrotechnicians working and living conditions
- promoting S&T in village and township enterprises to accelerate the use of modern agricultural technology and scientific management and assist them develop new technology intensive industries that also broaden the opportunities for employing surplus rural labour.

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1 Fan, S. and Pardey, P.G. 1992, "*Agricultural Research in China: Its Institutional Development and Impact*" The Hague, International Service for National Agricultural Research, 96pp

> Such technologies should also be extended as rapidly as possible to help the farmers in rural areas where poverty is endemic.

In addition to these objectives for the rural sector, the statement also recommends a strengthening of agricultural research and a continuation of the restructuring of the existing system of agricultural research institutes, and especially the management of the system, to strengthen its capacity for research and the production of relevant technology to link to the market economy.

Progress in Implementing S&T Reforms in Agriculture

The general impression, gathered by the Mission, of the impact of the S&T reforms on Agricultural research and technology was positive and the staff of the research institutes interviewed at State and Provincial level agreed that the reforms have improved the research environment through the devolution of greater responsibility to the Research Institutes and through the greater mobility of the staff, although the latter has been largely restricted to the younger well trained scientists. There has also been an increase in the interaction between the research staff and the end users of the technology, although this has not yet yielded sufficient funds to permit any reduction in the governments appropriation for the operational program of the Institutes. At the same time the policy reforms have done much more to revitalise the rural sector.

The Research and Development System

Any overview of the impact of policy on agricultural research in China has to acknowledge that, although the organization and management of the system is quite similar throughout the country,the quality and performance varies considerably. At the same time, the system is in the process of transition as a result of the policy reforms being undertaken to meet the changing requirements of the rural clients.

It is difficult to gain a comprehensive impression of any changes in the effectiveness and efficiency of China's agricultural research service, because of the large size and complexity of the system, and involving as it does different sources of funding and management at State, Provincial and County level and a very large number of research institutes and staff[2]. For these reasons, the impact of the policy reforms are not easy to measure; nor is it simple to distinguish these impacts from the effects of the repositioning of research programs which is under way in some Institutes in response to expected demand from the market place. Apart from these moves and the response to requests for training and technical advice on the design and operation of the projects for the Spark projects, the R&D system has been slow to take advantage of the market orientated policies for a number of reasons.

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[2] See Fan and Pardey, op cit

- One reason is that most research staff, (with the exception of those involved at the prefectural and county levels who deal with the application of research at the farm level), are not experienced in extension, or in dealing with farmers at a commercial level .Many of those who are active and successful in their research resent the 'diversion' they see being caused by being involved in extension work, as it detracts from the time available for research. On the other hand, those prepared to become involved in the transfer of research results often receive no financial rewards for their efforts.

- Other reasons are that many farmers and farm organisations are not prepared to pay, or are not in a position to pay for technology. In some cases, where high quality seed or propagation material of perennial trees are offered, payment is less of a problem, but where the advice or technology is related to an area regarded as "public good" research, there is an expectation from past experience that it should be provided free of charge. The new TVEs, especially those that have funds for accessing R&D, are more likely to request help and be prepared to pay for the technology but the scale of charges is quite low.

Although the ability of the agricultural research institutes to participate in the market orientated reforms has been limited, there is evidence that some of the actions being taken are having a positive influence. These include some restructuring of the programs of the research institutes to focus more closely on research topics which better cover the research needs of the expanding rural TVE programs in their regions.

The SPARK Program

This program has been one of the most successful outcomes of the S&T policy reforms for agriculture . The program has now spread to virtually every Province in the country and has helped to develop a total of 58,000 projects and many more individual enterprises within these. The sales from the projects in 1995 is estimated to be in the vicinity of 260 billion yuan, and an additional 20 million people have found employment in rural areas. Possibly the greatest impact has been in the increase in the annual per capita income of the rural population in those areas where the Spark program has been active . In the case of a TVE visited in Jingyang County in Shaanxi,there had been almost a three fold increase in the per capita income of the population of the county over the previous ~~the~~ five years and the target is to raise it to an average of 5,000 yuan per capita per year by the year 2000.

The Spark program is achieving one of the primary objectives of the policy,to stimulate and modernise the rural economy and improve the living standards of the farmers and their families.

Further details of the program and its achievements over the first 8 years are given in the proceedings of a recent conference[3]

Observations by the team and from reports and discussions with officials of the Spark program suggest that a number of factors have contributed to the success of the program.

Firstly the program is flexible and farmers can select from a wide range of well developed technologies (projects) to suit the particular region or district. It is also well linked into the local agricultural and or industrial market systems. As a result the nature of the resulting town and village enterprises (TVEs) in a given region or province vary considerably. In general there is an increase in the number of enterprises based on the production or processing of agricultural commodities relative to industrial enterprises across the country from East to West. Other features of the Spark programme that have contributed to its success are:

- the choice of a particular project within the program lies with the participants
- the incentive to join the program is based on the prospect of receiving a greater income
- the selection of the leader of a TVE is in the hands of the participants (subject to approval)
- support is provided for training of the participants and for the provision of technical advice
- the enterprises are funded almost entirely from bank loans and from capital raised by the participants and not government grants which tend to include more bureaucratic requirements
- a considerable effort is made to ensure that market outlets are available for the products of the enterprises.
- the technologies used in the Spark program tend to be already proven, in practice.

One important outcome of the Spark program is the focus it provides for the agricultural research system operation in various parts of the country to reorient their research programs to service the needs of these rural clients. It also provides new and improved technologies to expand existing enterprises and to provide the opportunities for new spin- off enterprises that have the ability to exploit new niches in the evolving markets

The response of research institutions to these new opportunities provided in the Spark program has been disappointing. Apart from the inputs mentioned above in respect of the design training and start up of the enterprises, there is little evidence of the research institutes exploiting this opportunity to explore new research opportunities in partnership with the more advanced enterprises. This would allow new technologies to be evaluated under realistic commercial conditions and if successful extend to other similar enterprises. If the research institutes are to give

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[3] Anon, 1994. International Program on China's Spark Program. Hangzhou, China. Published by SSTC, Beijing.

effective leadership in S&T in the rural community, they will have to be more proactive, so that the new research technologies are developed and evaluated in time to meet the growth in demand.

Utilisation of Other S&T Policy Initiatives by Agricultural R&D

The development of spin-off enterprises by research institutions in agriculture is not common but there is good evidence from the experience of The Shanghai Academy of Agricultural Sciences that this form of commercialising agricultural technology can be highly profitable.This Academy has several enterprises developed by its research institutes, the most successful being the Shanghai Mushroom Company which exports edible fungi to Japan to the value of 32 million yuan per year. Other Provincial Academies and individual research institutes in the country who have not yet exploited this opportunity should consider it .

The main source of grants for the agricultural research institutes is provided from SSTC's R&D grants scheme which is administered by the respective Ministries . This is a competitive grant and provides much of the research funding for the Institutes, both National and Provincial. In addition, many of the Provinces have additional grant schemes sourced from their own funds.

Other research initiatives developed by SSTC over the last ten years, such as the Torch Programme, the National Key Laboratory Program, and the National Natural Science Foundation, all provide research grants on a competitive basis to agricultural research scientists, but relatively few awards are made, partly because of the more applied nature of the research in agriculture which may discourage applicants, and possibly because it is easier to obtain funds from the R&D grants administered by the Ministry of Agriculture or Provincial sources.

A recent evaluation of the key R&D program in the Eighth 5-year plan, administered by SSTC and the State Planning Commission, commented on the difficulty of coordinating this program which has too many levels of management and relies on other Ministries and Agencies to implement the program .Other problems involved reporting and serious delays in the provision of funds, management at the project level and the relevance of the research topics, many of which are long term and lack focus within the major priority areas for research.As this program represents 65% of the S&T in agriculture it is urgent that these funds are utilised more effectively.

Extension

There has been a major emphasis in the policy reforms on the transfer of technology through a market driven process .This works well in the industrial sector where technology is a merchantable commodity. In the natural sciences this approach also has relevance and is being applied, but in general there are less opportunities and it will take longer to change the attitudes of the scientists and their clients to the concept of buying and selling information and technology. This is particularly true in agriculture, where much of the research is of a 'public good 'nature and the returns are reflected in the improved economy of the rural sector.

Another tradition in agriculture has been that the transfer of research results has been the responsibility of the extension service which is employed for this purpose. Although this system has not in general been very successful in China,, such a system is in place and it has a role to play in the new policy environment

The principal agricultural extension agency at the national level is the National Agricultural Technical Extension Centre which is concerned largely with the formulation of government policies, whereas at the Provincial level,the extension is organised under the Departments of Agriculture and Forestry. In the past, institutional boundaries and fragmentation has led to competition for resources and duplication of effort between research and extension which has not been productive Another problem now facing the extension service, as a result of the market reforms and the decentralisation of production units through the responsibility system, is the need to service a very large number of individual farming families rather than the collective production teams in the former commune system.

Some new developments funded by the State and Provincial governments are attempting to improve this situation by developing large collaborative programs involving research and extension personnel to undertake major development and extension projects such as the Liaoyuan project in Guangdong . The Harvest Program developed by the Ministry of Agriculture uses a similar approach and has been taken up by a number of the Provincial Academies of Agricultural Sciences

Factors Constraining the Full Impact of the S&T Policy Reforms

Research, Extension and Funding

Science and technology for agriculture has consistently received the highest priority in the successive 5-year plans and also in the S&T policy reforms, but the support received has never quite matched the rhetoric expressed in the policy statements. Part of the reason is that, despite the importance of agricultural research and the vital role it has to play in the future of China's rural development, the returns to investment in agricultural research, given the size of the research service and the number of research institutes and scientific staff, are not as high as they could be. The reasons for this are discussed in the following section in conjunction with the three major goals for the S&T reforms in Agriculture, as set out in the 1995 policy decisions on accelerating scientific and technology progress. The diagnosis and changes suggested are drawn from experience with similar problems in agricultural research systems in Western industrialised countries.

Goal 1

Developing a Modern Effective Agricultural Research Service

Many of the problems lie in the complex structure of the agricultural research system with research conducted in the Research Institutes of the Academy of Agricultural Sciences at the National level,also in key National Universities and in the Provincial Academies of Agricultural Science all of which operate independently. The lack of coordination resulting from this fragmentation (not to mention other agricultural research institutes including those operating under CAS and Ministries other than agriculture) leads to unnecessary duplication and competition for resources. Also the disciplinary and or commodity basis for research institutes and the major research focus on the production aspects of agriculture does not permit the necessary effective interdisciplinary interactions at the research level which are essential for solving complex agricultural problems . It also largely excludes the post production problems including postharvest issues and those associated with processing the products of the production systems.

If China's agricultural research service is to become a 'pace-setter in the world's advanced agricultural S&T', it will be necessary to overcome factors limiting the full integration of research and technology with the rural economy by reorganizing the structure and management of the current agricultural research systems.

The organization of research in the natural sciences in industrial countries has moved away from single commodity or disciplinary research institutes towards a more multi-disciplinary model, located when possible in a major agricultural eco-region so as to address the special problems and opportunities of the commodities (plant and/or animal), resources and environments in the region. Such regional research centres are usually well equipped with a critical mass of scientists in the major relevant commodity and disciplinary areas. They are responsible for both the strategic and applied research in the region. Collaboration with the other national research institutions (CAS, agricultural universities) located in the region together with provincial research institutes is essential X to prevent duplication and to obtain assistance with provincial problems that form part of the regional priorities.

In China, this model is one that might help with the solution of a number of problems that were discussed repeatedly during the Mission's visit, including:

- Lack of interaction and the resulting duplication among research institutes, agricultural universities/colleges at national and provincial levels, and the strong commodity and/or disciplinary focus of the research at all levels of agricultural research.

- The need for a more comprehensive set of research priorities, including new research opportunities to support the needs of the farmers and the agricultural TVEs in the different regions.

Goal 2.

Strengthening Scientific Research and Technology Development

The earlier contributions of the agricultural research system which helped raise productivity to record levels in the post 1978 period came largely from the application of research solutions to what have been called first order research problems, such as the introduction of improved crop and animal varieties, improved use and distribution of irrigation, the use of fertilizer and the application of pesticides to control pests and pathogens. The big gains from these inputs have now been achieved and substantial further gains in China's agricultural production, which will be required from a declining land area, will require solutions to more complex, interactive so-called 'second order' problems.

These second-order problems will require a more 'strategic' (basic) multidisciplinary research approach, which will need well-trained scientists equipped with more sophisticated laboratory and field equipment and facilities. Some examples of these problems include the decline of factor productivity of the more intensively-cultivated cropping soils, the need for better biological solutions to the problems of new pests and pathogens, and the search for improved quality and marketability of many of the current agricultural products.

With some notable exceptions, China's agricultural research has been slow to make the change, which began in the more industrialised countries in the late 1960s. The provision of advanced training to China's agricultural research community will be a considerable task. As of 1990, only 0.2% of agricultural researchers in China had PhDs, which is half the national average[4]. The agricultural research system is changing; however, with such a large and expensive research system, the changes may not be fast enough to keep pace with the demands of the rural sector.

Once the research system is more effectively structured, the next most common factor constraining the delivery of research results is the management and performance of the individual research institutes. The 5 criteria considered necessary for the development of an effective and creative research institute are:

- Critical mass of high quality and well trained research scientists.
- Experienced support staff with adequate equipment and facilities.
- Good leadership, delegation of authority, regular communication and clear, well focused research priorities.
- Incentives in the form of improved personnel policies, living conditions, training, overseas travels, greater mobility and flexibility in employment.
- Funding to develop collaborative research activities for mutual benefits and to access new skills, equipment and facilities.

The S&T reforms have helped to speed up the attainment of these criteria, but there is still some distance to go. Some of the most important requirements include:

- Strengthening the training and research skills of new young scientists which should not be restricted to the graduates from agricultural universities, as many of the new skills required are from other related science disciplines.
- Provision of modern equipment to permit a more in-depth approach to solve the more complex second order problems that constrain agricultural production.
- Greater opportunities to undertake research leadership training, develop methodology for priority setting and open up new research opportunities in fields such as post harvest technology, food processing, biotechnology, resource management, development of improved feed and fodder for livestock and the utilization of hilly lands for wood, fruit and animal production.
- The competition for able young scientists to work in the private sector will increase in future and it is essential that the research organizations provide salaries and conditions that will attract them to continue working in research. The quality of these people and their willingness to remain in research positions long enough to develop successful technologies will be critical to meet the growing demand for improved technologies in the rural sector.

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[4] See Fan and Pardey, op cit

- Collaborative research has become an important mechanism in advanced western countries to overcome institutional and administrative barriers between complementary groups in research institutes, university departments and industry. It has proved to be an efficient way to undertake multidisciplinary research, while at the same time ensuring the relevance and ease of transfer of technology resulting from those research activities.

Goal 3:

Improve the Process of Research and Technology Transfer to Stimulate the Economic Development of the Rural Sector

Difficulties with the transfer of agricultural technologies are endemic in most countries and have not been solved by establishing large extension services, often in different Ministries and usually separated from research institutions and under a different form of administration. There has also been excessive focus on the means of transfer rather than on the transferability of the technology which comes down essentially to the question " will the adoption of the technology be of benefit to the end user and ultimately increase his or her profit margin"

The new S&T policies offer a new dimension for future extension activities in agriculture through the introduction of the concept of market driven technology transfer, which *de facto,* is becoming the norm in many developed countries. Although the adoption of this approach in the agricultural research institutes has been slow, with the training of the staff and the growth of the agriculturally based TVEs, this approach will expand .One modification of the current structure of the research institutes that might assist the process would be to group those staff members, not skilled or interested in research, together with staff of the provincial extension services, in a special research division within the research institutes whose responsibility might include the design, evaluation and extension of research technologies . Such a group would be closely associated with the other research divisions in the institutes, but would have a clear responsibility to evaluate the technology and move it out to the end users as rapidly as possible .To overcome the problems associated with additional funds ~~associated~~ obtained from the commercialisation of research technology,a proportion of all funds derived from these sources could be shared with the entire research staff as part of the incentive for developing effective research .

In this respect the development of the new rural enterprises under the Spark program provide a valuable new opportunity for the agricultural research and extension activities. They provide a useful framework against which the research programs can be better orientated and research priorities developed to service the current and likely future needs of TVEs and the regional farmers in general.This for example would also permit a better balance between the production and post-production activities, which is urgently needed to respond to the growth in the food processing (value adding) industries.

Research Funding

The support for agricultural research at the National level is derived from the State Planning Commission through SSTC to the Ministry of Agriculture and Forestry who administers the funds for both the Academy of Agricultural and Forestry Sciences research institutes and also the Key Agricultural Universities. At the provincial level, the funds for the equivalent institutions come from the provincial government . These funds cover the operational budgets . The resources for research are obtained largely from the Key R&D Program administered by SSTC through the Ministries of Agriculture and Forestry, which in the case of agriculture covers 65% of funds available for R&D .Other grants are available research projects in the provincial research institutes, largely from local government funding . Both national and provincial research institutes have access to funds from other SSTC initiatives such as NNSF and other special projects supported by the Ministries.

The funding for agricultural research has not been reduced as has been the case for many of the industrial and engineering based research institutes to provide an incentive to respond to the market for technology. If anything it has increased in real terms especially at the Provincial level,however owing to the increase in total staff in recent years the funds available per researcher have declined[5]

To develop a high quality research service the funds made available to those engaged in good quality modern strategic research should increase substantially to enable the staff involved to obtain better training and be able to procure the necessary equipment and facilities needed for modern research .One of the current problems is that there are too many researchers and research institutes and if this problem could be resolved by creating fewer, more comprehensive and better staffed and equipped laboratories, the existing investment would be better spent.

Levies on commodities can provide an additional source of revenue for research. This approach is already being utilised in several provinces . It is a very common practice in advanced agricultural economies and involves striking a levy on major commodities and collecting at the point of sale.These funds are then distributed by the appropriate authority to the relevant research groups based on the priorities jointly approved by representatives of the S&T authorities and the producers. This type of tax on production for research is particularly appropriate for commodities such as grains that benefit from public good type research.

[5] See Fan and Pardey, op cit

S&T Reform policies and environmental development

During the decade 1985-1995, two related trends appear to have taken place in China's environmental development: the combined effects of rapid industrialisation, increased agricultural production, and growing population pressure, have caused environmental degradation in rural and urban areas. At the same time the decade of S&T reforms have increased the attention paid to environmental sciences and technology. What happens to China's environment has significance at the global scale. The decade of S&T reforms have generally reinforced the importance accorded to environmental R&D for China's economic and social development by the Government. After the Stockholm Conference on the Environment in 1972, and even more so after the UN Conference on Environment and Development in 1992, increasing attention has been paid to the problems of environmental quality and natural resource depletion by the Chinese leadership, and this has been accompanied by supportive S&T policies.

The key processes of the S&T reforms affecting the environmental sector include:

- stimulating institutional reform through declining government budget allocations;
- creating a market for environmental research and technology;
- setting strategic scientific research priorities;
- the impact of the Spark Program for rural development on the creation of many new point sources of pollution;;
- establishing the Torch Program for New Technology Enterprises;
- opening up of China to international science and technology forces;
- establishment of China's Agenda 21 Program .

The Mission Visit, both the site visits and discussions with Chinese experts and officials, provided the following impressions of progress and difficulties in meeting the S&T reform goals through the prism of environmental development.

Stimulating institutional reform through declining government budget allocations.

The decision to force S&T institutions to respond to the market by cutting their operational budgets was implemented over the period 1986 - 1990. Three main types of institutions were distinguished for differential cutting, depending mainly on their assumed ability to market their goods and services; technology development; basic research; and public welfare S&T institutions. Both agricultural and environmental protection S&T institutions were classified as undertaking 'public good' research and were relatively protected from the impact of the reform policy on their structure and organisational cultures'. In 1991, at the end of the implementation period, the resulting budget breakdown shows that environmental S&T institutions continued to receive 72% of their budget from national government (Table 7.1)

Table 7.1 Sources of income for S&T Institutions in 1991

	Govt.	Market	Bank loans	Other
Ind. tech.	22%	61%	12%	4%
Agric.	55%	33%	5%	6%
CAS	68%	21%	1%	10%
Environ.	72%	27%	2%	<1%

Source: SSTC, 1992.

New environmental institutions were created during the period of budget reforms: these include a CAS Institute on Environment and the Committee of Environmental Protection and Natural Resource Conservation of the National People's Congress, which was created in 1992 to oversee the development and implementation of environmental legislation. In its visits to environmental S&T institutions, the Mission was told that opportunities for earning income from the market for environmental technologies are very limited. However, experience from other countries would indicate there are perhaps more opportunities than are currently being explored; for example, in the area of environmental consulting and environmental impact assessment and risk management. Additionally, and more tellingly, the Shanghai Light Industries Research Institute has demonstrated that niche markets are to be found for any institution with the drive to identify them These are likely to be growth areas in China within the next few years and are fields where Chinese skills should be developed, rather than relying on foreign consultants.

Within environmental S&T institutions, restructuring to reduce the number of departments, to identify the core (tenured) personnel, and to facilitate multidisciplinary project teams are taking place similar to those found throughout the S&T system. We saw less evidence that effective horizontal linkages were being created between institutions, either between different CAS institutions working on environmental issues, or between CAS, CAAS, and line Ministry institutions which are working on closely related issues, and which would benefit from greater interaction; for example, in the fields of sustainable agriculture, or land and water management. Some coordinating institutions exist at provincial and local levels, but they indicated that their ability to coordinate the work of *national* S&T institutions located geographically in their jurisdiction was limited.

The research system in China, as in other countries, is generally structured along disciplinary lines and interdisciplinary research has to overcome organisational boundaries both within and between institutions. For environmental research, this is a major challenge, since environmental problems require the inputs of many disciplines, both in building models and in empirical research. Research institutions at both national and provincial levels are restructuring and this may facilitate more interdisciplinary research. The establishment of strategic research grants for interdisciplinary environmental projects will further these reforms. The current rethinking of the structure and role of the Chinese Academy of Sciences might also take the particular needs of environmental research into account, and strengthen the linkages not only between the various environmental sciences, but also between them and policy research.

The Mission received the impression that for the environmental S&T sector, there was more progress to be made in improving the coordination between research institutions and between them and the production sector. This further rationalisation of the environmental S&T system could bring benefits in eliminating duplication of research effort, and better meeting the research needs of the different regions of China by responding not only to national priorities, but also to those priorities defined by provincial S&T authorities. Thus, while we were impressed by the work and achievements of many individual institutions, we were less convinced that the environmental S&T institutional *system* was as cost-effective and innovative as it could be.

Creating a market for environmental research and technology.

Environmental S&T institutions cover a wide spectrum from basic research on earth sciences and ecology to environmental pollution control technology. They do not form a coherent group either in terms of disciplinary backgrounds or orientation to the market. The Chinese Government has identified basic environmental sciences as a strategic national priority for research, both in relation to sustainable food security and global environmental change. These are the parts of the environmental S&T system that they are prepared to "*anchor*" while other components, such as environmental control technology are encouraged to enter the marketplace.

Particularly important for China's development, among the market-oriented components of the environmental S&T system is innovation in developing a domestic environmental protection technology sector; cleaner production technologies for manufacturing and clean energy production, especially clean-coal technology. In each of these areas, China is faced with major and urgent environmental impacts, a domestic capability that lags behind other industrialised countries, and a desire to become technologically advanced. International concern about China's rising contribution to global change, and Japan's self-interest in reducing the acid precipitation believed to originate in China, has meant that international assistance and joint ventures are providing the necessary capital to help develop these sectors.

The technology transfer process is planned to begin with importing advanced equipment and expertise (including not only technology but also management systems, quality certification and information services) mainly through joint ventures, and then to build up a domestic environmental protection and monitoring production sector. The task is formidable, as it involves both the debt-burdened and inefficient state-owned enterprises and the small and widely dispersed township enterprises. China currently has more than 1,800 enterprises producing environmental protection equipment, 80% of which are township enterprises, producing products of variable quality, and which are probably themselves polluting the environment in the manufacture of the equipment.

There is also a potentially very large market for environmental information services in China and overseas, and this opportunity seems to the Mission to have been less explored by the environmental S&T institutions. The Chinese Government has already allocated USD 3 million, plus annual maintenance costs, for the establishment of a National Climate Centre, which will bring together research in climate modelling and scenario analysis, experience in response strategies, and long term geological and historical data. Few countries have such a richness of historical record to combine with advanced modelling and with GIS data. Environmental information and analytical research has also direct application to land use zoning applications, environmental impact assessment for infrastructure projects (such as the major ones planned for water diversion and transportation), and the expanding market for environmental risk assessment. The Government would itself be a major consumer of such services, and there is a need for government support to basic research, but it may be worth expoloring how far such a national Centre and similar environmental information sources could generate some revenue by selling their services to a market that would include the large number of new foreign investors in China's developing economy.

Environmental scientists and engineers have benefitted from the policy reforms to enhance the status of intellectuals and S&T personnel within society, but the Mission did not see much evidence of large numbers of environmental scientists leaving the S&T institutions to join or to start enterprises. Rather the reverse: despite declining institutional budgets, we were told only a few scientists were leaving the environmental S&T institutions, while more were taking a second job, often environmental consulting. The degree of mobility of environmental scientists is likely to vary widely between scientific disciplines and geographic location of the institutes, which the Mission was unable to assess. We believe that the socialist market economy presents more opportunities for mobility than seemed to be taking place at present.

Setting strategic research priorities

The Mission was impressed with the degree to which China has articulated its strategic research priorities for the medium and longer term. The establishment of a competitive allocation process for basic and basic applied research through the National Natural Science Foundation of China in 1986 led to priority-setting even within the part of the S&T system which was to remained anchored to government support. Overall, environmental research ranks high among the priorities within the general, key and major programs of NNSFC funding. Environmental research areas given priority for funding include clean energy sources and energy saving processes, environmental chemistry, pollution control, a broad number of priorities within earth, atmospheric and ocean sciences`, and a major strategic program on global change research (NNSFC, 1995).

This commitment to support basic research in earth and environmental sciences is important, not only to China, but internationally as global change research now ranks as "big science", or involves, in OECD's terms, "megaprojects". It requires large amounts of funding and international coordination of national priorities for research funding because the current generation of global models of earth-ocean-atmosphere interactions require comparable data inputs from around the world. China is playing a leading role in global change research and the associated international research programs (Ye Duzheng, Lin Hai et al, 1995). The S&T reforms have thus strengthened the contribution of China to international research in global change.

The environmental impact of the Spark Program for Rural Development

The impression gained by the Mission is that, partly as a result of the S&T reforms, particularly the establishment of thousands of township enterprises throughout the rural areas largely through the Spark Program, the environmental "challenge" to the S&T system is considerably greater now than at the beginning of the decade of reform, and the environmental policy response will have to be correspondingly more innovative to be effective. The township enterprises include many that are highly polluting in the traditional sense, such as coal mining, cement making, pulp and paper, and brick-making. They also include new industries such as pharmaceuticals, fertilisers and plastics, which create waste that is less visible but both more difficult to monitor and which can be locally very harmful to human health and to the environment.

The township enterprises have been very successful in absorbing rural labour and increasing rural incomes. In 1994, township enterprises accounted for about 75% of the rural GNP and employed 28% of the rural labour force, or more than 120 million people. They are the source of 65% of the net income of Chinese farmers and now employ more people than the state-owned enterprises. By 2000, township enterprises are expected to account for 45% of China's GDP, and 80% of the rural GDP. They are expected to grow especially rapidly in the central and western inland regions where there are preferential policies (Ministry of Agriculture, 1995).

Township enterprises are thus a major force in national development and in income generation for the rural areas. They are seen as growth poles for new towns and industrial zones and a mechanism for regional equalization, through a program of east-west cooperation and management training. These township enterprises are likely to create thousands of point sources of pollution, affecting air, water (surface and groundwater)and land, unless more emphasis is given both to strengthening environmental monitoring and to ensuring that the technology packages provided through the Spark Program are clean production technologies. As has been the experience of the state owned enterprises, retrofitting of old, polluting technology is expensive, and often neither technically nor economically feasible. The cost of trying to clean up millions of hectares of agricultural land and the associated water bodies, would seriously affect China's economic growth, and is best avoided by accelerating the process of environmentally sound policies for township enterprise development as a matter of urgency.

On the basis of what we heard and saw, the Mission also felt that the program of environmental monitoring and regulation for township enterprises could be improved, and that perhaps here was a role for more cooperation between the scientific institutions, some of which have analytical capability for measuring pollutants and local Environmental Protection Agencies, which generally do not.

More broadly, the approach to environmental regulation in China as in other countries is shifting from "downstream" or *end of the pipe* control to more upstream" anticipatory and preventive policy instruments. The difficulty of the current emphasis on the 'polluter pays' regulatory principle (even including the death penalty)is that many of the township enterprises, once established, have little economic or technical capacity to adopt cleaner production technology, to pay significant fines, or even to monitor their own emissions. Thus, in rural industrialisation policy, the S&T reforms have created an environmental moving target for themselves, necessitating the need for further reform in S&T priorities, system renewal and performance. This is not unique to China, although the speed and scale of rural industrialisation in in China probably is. The challenge is to find an appropriate Chinese package of S&T initiatives to deal with this second generation environmental problem.

Establishment of China's Agenda 21 Program for sustainable development

The various initiatives relating to environmental protection and natural resource conservation that feature in earlier S&T reform programs are brought together in the White Paper on China's Population, Environment and Development in the 21st Century, 1994, known as China's Agenda 21. This comprehensive strategy document will function as a guideline for drawing up medium and long erm plans on economic and social development, and its goals and programs will be included in both the Ninth Five-Year Plan (1996-2000) and the Plan for 2010.

It was prepared by a leading group co-chaired by a deputy Minister of the SSTC and a deputy Minister of the State Planning Commission who coordinated the input of 52 ministeries and agencies and more than 300 experts during 1993. China's Agenda 21 was adopted at the 16th Executive Meeting of the State Council on 25 March 1994. It includes 78 program areas with goals and objectives, of which nine priority programs have been identified as the first tranche for funding and action. It is anticipated that 60% of the funding for implementation will come from China and 40% from international sources through assistance, cooperation and investment. It was reported during the Mission Visit that already USD 3 billion have been committed from international sources, primarily the World Bank, the Asian Development Bank and Japan.

The nine priorities for the first tranche of the Agenda 21 Program are:

1. Capacity building for sustainable development;
2. Sustainable agriculture
3. Cleaner production and environmental protection industry
4. Clean energy and transportation
5. Conservation and sustainable use of natural resources

6. Environmental pollution control
7. Combatting poverty and regional development
8. Population, health and human settlements
9. Global change and biodiversity convention.

The preparation and approval of the White Paper on Agenda 21 and the establishment of Coordinating Committee to oversee its implementation, are evidence of the importance that the Chinese government at the highest levels attaches to making environmental protection an integral part of economic and social development. It is a major achievement in integrated national planning for sustainable development, and is a leading model for other countries. The Mission was also impressed with the awareness that we encountered at all levels not only of the importance of maintaining environmental quality and of the main environmental problems in their area, but of the Agenda 21 Program itself. The coordination achieved in setting out the priorities and projects in Agenda 21 shows what can be achieved across the S&T system in terms of collaboration and multidisciplinary research focussed on economic and social development.

Deepening the S&T reform process for the environmental sector.

The Agenda 21 Program anticipates a further development of the legal, policy and educational basis for sustainable development, and, in the view of the Mission, this is a necessary corrollary to the current priority accorded to environmental S&T in China.

During the 1980's, a number of key environmental and natural resource protection laws, regulations and standards were enacted. These rely heavily on administrative regulation, including the ability to monitor environmental quality at the local level, and embody the "polluter pays" principle. The Chinese Government have already identified where there are short term needs to fill in specific gaps in the current legislation. Among the important new legislation being developed is that for solid waste pollution and for the environmental management of township industries. More importantly, the national Government recognises that, in the longer term, the legislative and policy framework has to evolve towards policy instruments which are more consistent with a market economy. These include specific environmental taxes, pollution levies, tradeable permits and economic incentives. This is generally uncharted territory for any government, and particularly for China's unique development of its socialist market economy.

Important elements in this policy package include the **integration** of environmental protection and rational resource use into other policies, especially industrial policies; **policy feedback mechanisms** to assess the environmental impact of other economic, social and S&T reforms and to adjust them appropriately, **basic research in both environmental systems and policy analysis** to understand both the ecosystem and policy system behaviour and their linkages, and moving the policy emphasis *upstream;* that is, to rely more on **prevention than cure**.

Appendix 1

The Mission Team

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